

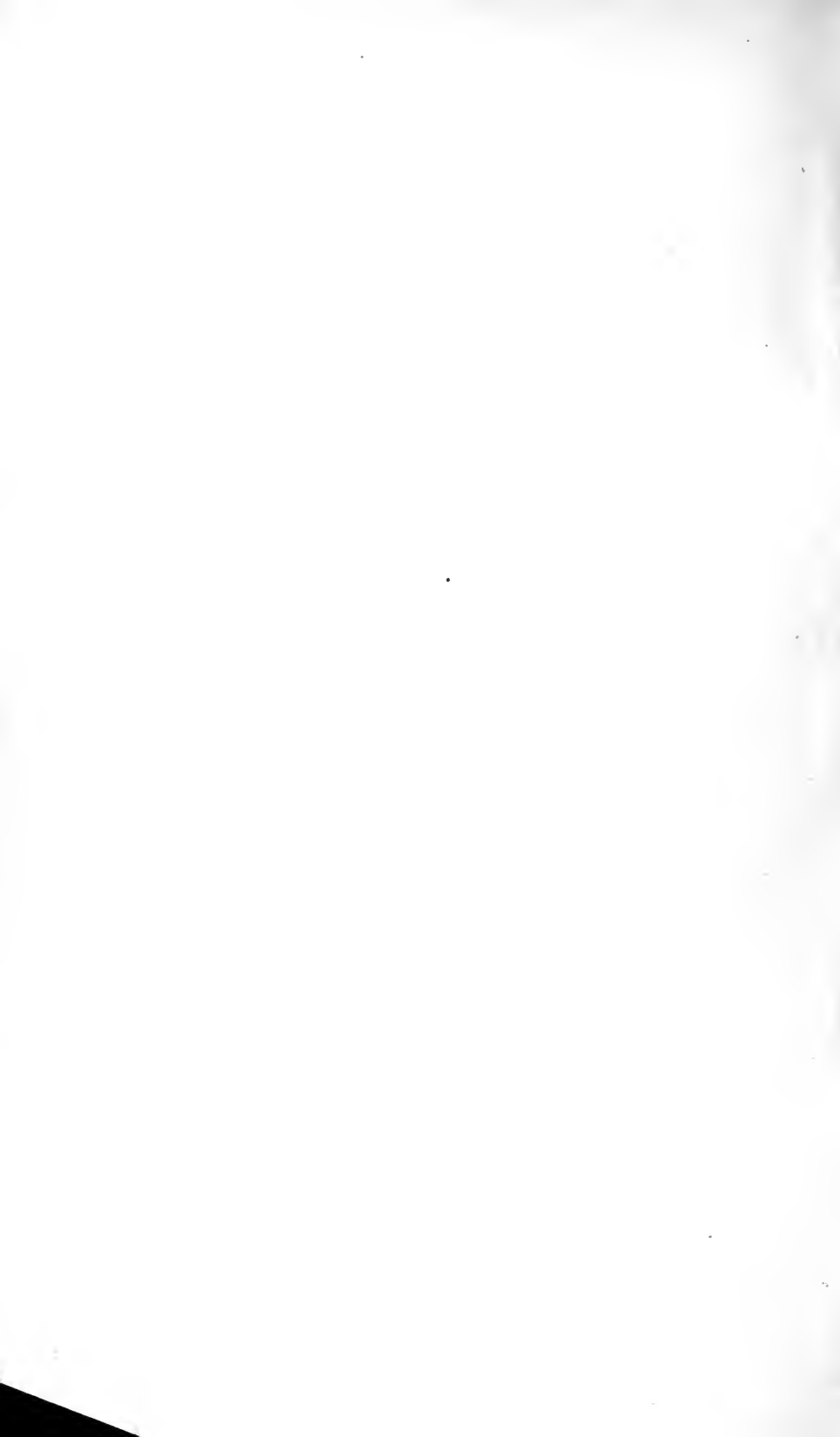


3 1761 05290401 8

THE  
THEORY OF STRAINS.  
DIEDRICHS.













THE  
THEORY OF STRAINS.

A COMPENDIUM FOR THE  
CALCULATION AND CONSTRUCTION OF BRIDGES,  
ROOFS AND CRANES,

WITH THE APPLICATION OF  
TRIGONOMETRICAL NOTES.

CONTAINING  
THE MOST COMPREHENSIVE INFORMATION IN REGARD TO THE  
RESULTING STRAINS FOR A PERMANENT LOAD, AS ALSO FOR  
A COMBINED (PERMANENT AND ROLLING) LOAD.

IN TWO SECTIONS.

ADAPTED TO THE REQUIREMENTS OF THE PRESENT TIME.

BY  
JOHN H. DIEDRICHS,  
CIVIL AND MECHANICAL ENGINEER.

ILLUSTRATED BY NUMEROUS PLATES AND DIAGRAMS.

BALTIMORE:  
SCHMIDT & TROWE.  
1871.

108000  
4.12/11

---

Entered according to Act of Congress, in the year 1871, by  
JOHN H. DIEDRICHS,  
In the Office of the Librarian of Congress, at Washington.

---

-----  
WESTCOTT & THOMSON,  
*Stereotypers, Philada.*  
-----

INSCRIBED TO

WENDEL BOLLMAN, Esq.,

IN TESTIMONY OF HIS INTEREST IN SCIENCE AND ART.

Digitized by the Internet Archive  
in 2007 with funding from  
Microsoft Corporation

# CONTENTS.

---

	PAGE
PREFACE .....	7
EXPLANATION OF CHARACTERS USED IN THE CALCULATIONS .....	11

## SECTION I.

A. INTRODUCTION.....	13
I. THE LEVER.....	15
II. SUSPENDED WEIGHTS AND THE RESULTING STRAINS.....	18
III. TRUSSES WITH SINGLE AND EQUALLY-DISTRIBUTED LOAD.....	21
Suspension Truss Bridge.....	23
Suspension Bridge .....	27
B. ROOF CONSTRUCTION .....	31
C. SEMI-GIRDERS.....	43
I. SEMI-GIRDERS LOADED AT THE EXTREMITY .....	43
Cranes .....	44
II. SEMI-GIRDERS LOADED AT EACH APEX.....	45
D. GIRDERS WITH PARALLEL TOP AND BOTTOM FLANGES	48
I. STRAIN IN DIAGONALS AND VERTICALS.....	48
II. STRAIN IN FLANGES .....	51
III. TRANSFORMATIONS.....	53
IV. GENERAL REMARKS.....	53
Directions for the Calculation of Complex Systems.....	54
E. COMPARATIVE TABLES OF RESULTING STRAINS FOR A PERMANENT LOAD.....	56
I. SYSTEM OF RIGHT-ANGLED TRIANGLES .....	56
II. SYSTEM OF ISOSCELES BRACING.....	58

## SECTION II.

GIRDERS CALCULATED FOR COMBINED (PERMANENT AND  
ROLLING) LOAD.

	PAGE
A. GIRDERS WITH PARALLEL TOP AND BOTTOM FLANGES	59
I. THE RIGHT-ANGLED SYSTEM.....	59
II. ISOSCELES BRACING .....	66
1. Triangular Truss.....	66
Calculation of Strains $y$ and $u$ in Diagonals.....	67
2. Isometrical Truss.....	69
a. Calculation of Diagonals.....	70
b. Calculation of Top and Bottom Chords (Flanges).....	72
B. CAMBER IN TRUSSES, WITH PARALLEL TOP AND BOT- TOM CHORDS.....	73
TABLES CONTAINING THE LENGTH OF ARCHES FOR DEGREES, MINUTES AND SECONDS, FOR A RADIUS AS UNIT.....	77
C. PARABOLIC GIRDER OF 48 FEET, OR 16 METRES, SPAN	80
D. THE ARCHIED TRUSS.....	86
Calculation of Strain $y$ in the Diagonals.....	88
Calculation of Strain in the Verticals $V$ .....	90
Transformations .....	93
E. THRUST CONSTRUCTION .....	94
I. GIRDER 20 FEET IN LENGTH (WITH A SINGLE WEIGHT AT THE CENTRE).	
II. GIRDER 72 FEET IN LENGTH (CALCULATED FOR PERMANENT AND ROLLING LOAD).	
Definition of Strain $x$ in the Horizontal Flanges.....	97
Definition of Strain $y$ in the Diagonals .....	98
Calculation of the Tensile Strains $z$ in the Lower Flanges.....	99
Calculation of the Verticals $u$ .....	101
III. CALCULATION OF A TRUSS SUSTAINING A DOME.....	102
Calculation of Strains $x$ of the Outside Arch.....	104
Calculation of Strains $z$ of the Inside Arch.....	105
Calculation of the Diagonals $y$ .....	106



## PREFACE.

---

THE want of a compact, universal and popular treatise on the construction of Roofs and Bridges—especially one treating of the influence of a variable load—and the unsatisfactory essays of different authors on the subject, induced me to prepare the following work.

Bridge-building has been and always will be an important branch of industry, not only to engineers, but also to the masses for the purposes of travel and trade, and, as Colonel Merrill in his recent essay on Bridge-building remarks, “important to railroad companies on account of the large amount of capital invested in their construction.”

Bridge literature has often been used by rival parties for the purpose of advancing their own private interests, their motive being competition. Imposing upon the faith and credulity of those whom they pretend to serve, there is no guarantee that worthless structures will not be erected.

Thoroughly independent of any such motive, my aim is to give, especially to bridge-builders and to engineers and architects, the results of my investigation on the subject of calculating strains, in order that capitalists and the public may be benefited and protected.

These calculations will also enable those who have but a limited knowledge of mathematics to acquire the necessary information. For this reason special attention is paid to the arrangement of the work, the whole being made as plain and simple as possible, in order to meet the wants of the common mechanic as well as the experienced engineer.

Though there are many valuable treatises of this kind, there has as yet been no work published serviceable to the degree desired by the practical builder or mechanic—most of the dissertations being too theoretical and hard to comprehend by one not versed in the higher mathematics; and some are so arranged that a clear understanding of the calculations is very difficult.\*

The most valuable work in the language is doubtless Mr. Stoney's "Theory of Strains," though the Method of Moments is not developed to that degree which I think necessary for the practical man.

We owe to the renowned German engineers Ritter and Von Kaven the universal application of this *Method* in the work entitled "Dach und Brücken Constructionen," in which it is fully explained by examples and illustrated by diagrams, these being often carelessly neglected in other works.

The above-mentioned work served me very much in the arrangement of this, which I hope will be kindly received.

The work being expressly prepared, as aforesaid, for the use of beginners in the study of mathematics, as well as for the

---

\* As an exception, may be named Mr. Shreve's brief but popular treatise in Van Nostrand's "Engineering Magazine," No. xx., August, 1870; Vol. III.

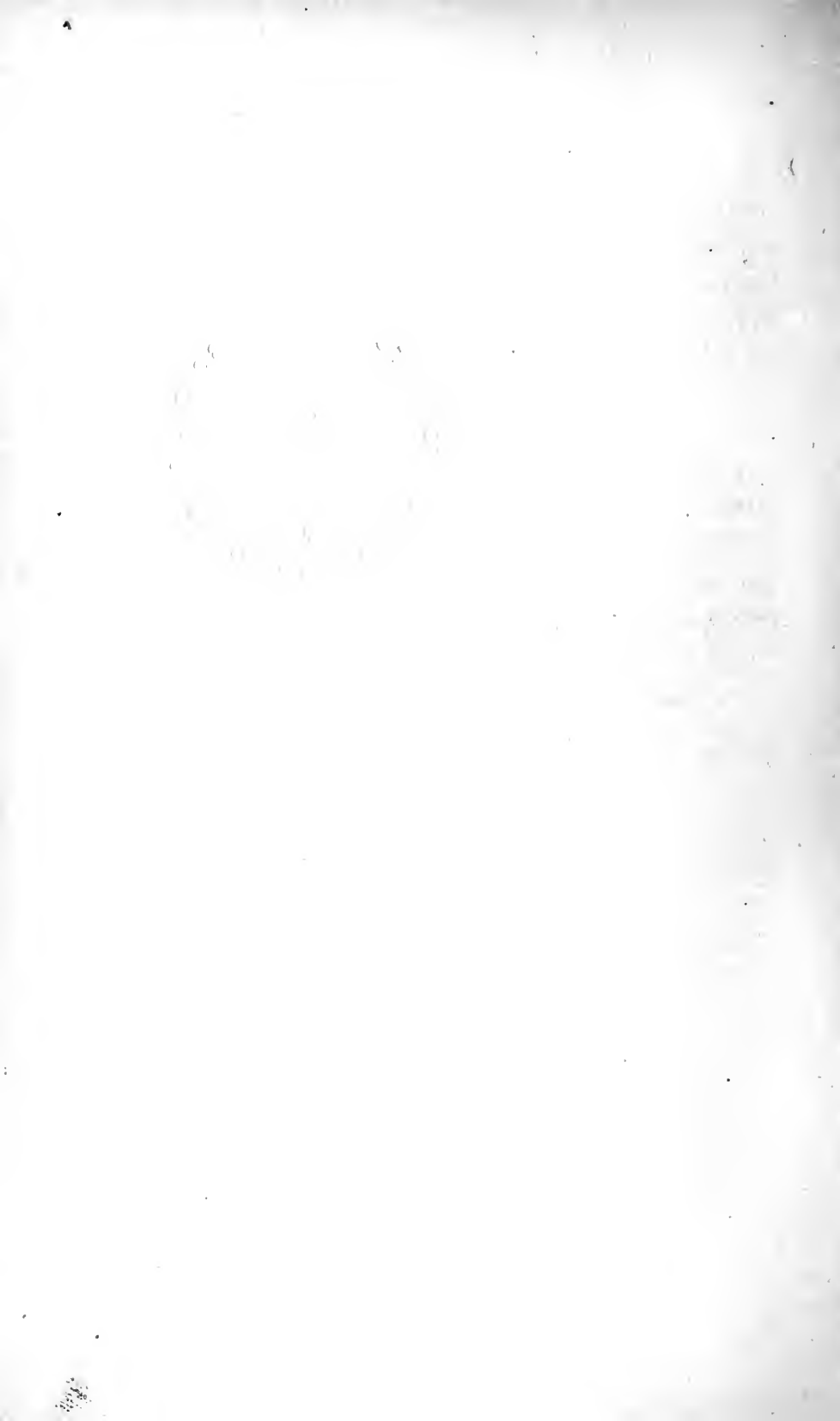
more advanced practical engineer, it will enable them, after a short perusal, to acquire all the necessary information, for which even the trigonometrical notes accompanying the general results are not really required.

The higher classes of colleges and other institutions of learning will find the work very valuable.

On account of the expense, an intended Appendix, containing a rational and concise investigation on "The Strength of Materials," had to be dispensed with; yet I hope with this volume to gratify not only the desire of friends, but to be able with great satisfaction to assist engineers in the pursuit of their high and noble calling.

THE AUTHOR.

OCTOBER, 1870.



## EXPLANATION OF CHARACTERS USED IN THE CALCULATIONS.

---

- $=$  Equal, or the sign of equality.
- $+$  Plus, or the sign of addition; also, the symbol of positive (tensile) strain.
- $-$  Minus, or the sign of subtraction; also, the symbol of negative (compressive) strain.
- $\times$  or  $.$  Sign of multiplication.
- $: or \div$  Sign of division.
- $,$  Sign of decimals; also, of thousands.
- $\infty$  Sign of infinite.
- $<$  Sign of angle, signified by the Grecian cyphers  $\alpha, \beta, \gamma, \delta, \epsilon$ .
- $^2$  Sign of square of a number.
- $\sqrt{\quad}$  Sign of square root of a number.
- $^{\circ}$  Sign of degrees.
- $'$  Sign of minutes; also, of feet.
- $''$  Sign of seconds; also, of inches.
- $( \quad )$  or  $[ \quad ]$  Brackets, to enclose the mathematical expression bound to the same operation.
- $\pi$  The number 3, 14, or periphery for a unit of the diameter.
- R Right angle, or  $90^{\circ}$ .
- $\perp$  Vertical.



# THE THEORY OF STRAINS.

---

## SECTION I.

### A. INTRODUCTION.

To enable the student to comprehend the work, and have a thorough knowledge of certain conditions and examples without studying the whole, it is necessary for him to understand the arrangement of the following pages.

On the first few pages and the appertaining figures at the close of the chapter is found a short description of the lever in its different appliances, the application being only a key to the calculations of strains which follow.

The trigonometrical notes are in many cases almost superfluous. Still, it may be advantageous in this way to accustom the reader to their use. The "Suspended Weights and Resulting Strains" are developed by the parallelogram of forces, and for a plain illustration the results are appended to the figures, which will also be observed on figures of "Trusses with Single and Distributed Load."

In the "Suspended Weights and Resulting Strains" a more elaborate calculation was thought necessary, and therefore an Introduction to the calculation by the "Method of Moments" may be found in its proper place.

This Introduction presents the beginner with a clear and comprehensive knowledge of the formation of Moments; and the equations for Figs. 20, 21, etc., explain the equilibrium of force and leverage.

At the close of this chapter is found the explanation of maximum compressive and tensile strain in the top and bottom chords of a parallel-flanged truss or girder.

On "Roof Construction" (B), Plates 6 to 11, remarks are un-

necessary. The builder can with ease find from the figures a system to suit his purpose. (See also "Arched Trusses," D, Section II.)

On "Semi-Girders" (C) the calculation of strains is treated in the way heretofore generally known (determining from the centre toward the abutment), after which the "Method of Moments" is applied to the same example, followed by a more elaborate explanation of the principles of Moments on the crane skeleton (Plate 14), whose single members are altogether divergent.

The thorough calculation of a truss with horizontal top and bottom flanges (right-angled system D, Sect. I.), with the resulting strains for a system of braces, all of which are inclined in the same direction, shows how easily by transformation of the strains a system of bracing just reversed can be formed. (Comp. D, Sect. II.)

From the comparative tables, E, I., II. (Plate 18, 19) those who are not mathematicians can find, by a little study (for an assumed load "W"—a variable load not considered), the strains in flanges, braces and ties. (See D, IV., Sect. I.)

The progress of panels, and by this the increase of stress in the different members, are *ad libitum* to be extended (are optional).

Where no composite strains appear, in the skeletons double lines make the compressive (—) strains more obvious, the tensile (+) strains being always represented by single lines. The assumed load in the calculations is equally divided on the apexes; but in general some attention may be paid to a peculiar load—say from a single locomotive—at a certain apex, this being observed in examples on "Suspension Truss" (III., Sect. I.).

The calculations in Sect. II. with regard to the influence of a variable load are more difficult to understand. Still, by the results of strains in the skeletons it is easy enough to form an idea about this matter, and to see the importance of counter-bracing or tying at centre of railroad-bridge trusses.

What experience and observation have already taught to the practical railroad man is here *fully* shown by figures.

Information is given on parallel-flanged trusses for the so-called "Camber in Bridges" at B, Sect. II., which to many builders has heretofore been only a matter of experiment.

Yet it is to be remarked that for the calculations E, Sect. II., Plates



29 to 34, a variation in the determination of the principal force will be perceived, the base of calculating "Thrust Construction" being the horizontal strain  $H$  and the vertical strain  $V$  at the vertex (centre), and not, as before, the reactive force,  $D$ , of abutments.

Farther explanation will be found in the examples and figures referred to.

The calculations of strains involve the supposition that the connections at the joints (apexes) are effected by link-bolts, thus relieving the single members (struts and ties) from all transverse strain. The equally-distributed load and even the weight of structure are supposed to be transmitted to the adjacent joints.

### I. THE LEVER.

Plate 1, ] When for a double-armed and compound lever (Figs.  
Fig. 1<sup>a</sup>, ] 1<sup>a</sup>, 1<sup>b</sup>, 1<sup>c</sup>) by  $P$ , a force represented, whose direction  
" 1<sup>b</sup>, ] right-angled to its arm or lever  $a$ , and when  $Q$ , a force,  
" 1<sup>c</sup>. ] acting at the leverage  $b$ , so are  $P.a$  and  $Q.b$  the "mo-  
ments," and for the equilibrium,

$$P.a = Q.b \text{ (fulcrum } f).$$

2.] For the single lever from Fig. 2,

$$\text{Mom.} = p.l = W.\frac{1}{n}.l,$$

$$p = \frac{W}{n}.$$

Example.—When  $W = 100$  lbs.,  $l = 20$  feet,

and  $n = \frac{l}{4} = 5$  feet;

so  $p \times 20 = 100 \times 5$ , or  $p = \frac{100}{4} = 25$  lbs.

3.] In the same way in Fig. 3,

$$p.l = W.\frac{1}{n}.l + W.\frac{2}{n}.l,$$

or  $p = W\left(\frac{1}{n} + \frac{2}{n}\right)$  and for  $n = 4$ ;

i. e., the weights suspended at a distance from the fulcrum equal  $\frac{1}{4}l$  and  $\frac{2}{4}l$ .

$$p = W \left( \frac{1}{4} + \frac{2}{4} \right)$$

or 
$$p = \frac{3}{4} W.$$

4.] Similar to this in Fig. 4, when the length,  $l$ , is divided in eight equal parts.

$$pl = W.l \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{5}{8} \right)$$

or 
$$p = \frac{W}{8} (1 + 2 + 3 + 5);$$

i. e., 
$$p = \frac{11}{8} W.*$$

5.] For a combined weight,  $W$ , and an equally-distributed load,  $q$ , from Fig. 5,

$$p.l = W.\frac{l}{4} + q.\frac{l}{2},$$

or 
$$p = \frac{1}{4} W + \frac{1}{2} q \text{ (fulcrum } f),$$

and 
$$p_1 = \frac{3}{4} W + \frac{1}{2} q \text{ (fulcrum } p).$$

\* For the summation,  $S$ , of figures from 1 to  $n$ ,

$$S = \frac{n(n+1)}{2}.$$

So for the sum of figures from 1 to 12,

$$\frac{12 \times 13}{2} = 78,$$

and from 1 to 15,

$$\frac{15 \times 16}{2} = 120.$$

Further, the sum  $S$ , from 1 to  $n$ , for  $n = \infty$ .

$$S = \frac{n^2}{2}$$

The sum of the square from 1 to  $n$ , or  $1^2 + 2^2 + 3^2 + \dots + n^2$ .

$$S = \frac{n^3}{3}, \text{ for } n = \infty.$$

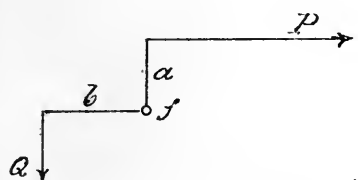
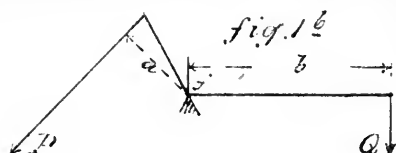
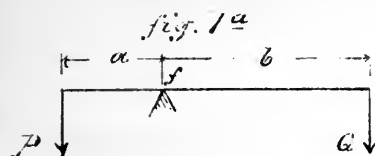
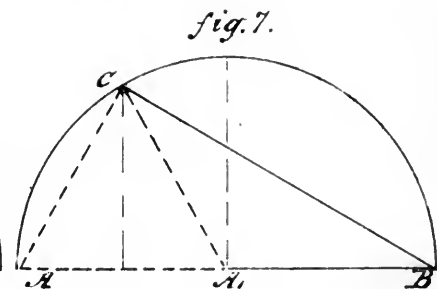
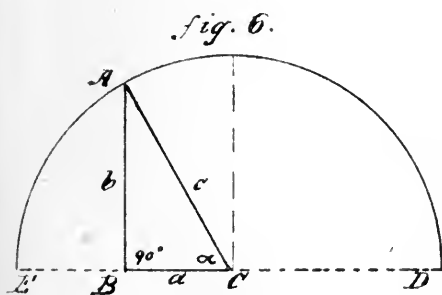
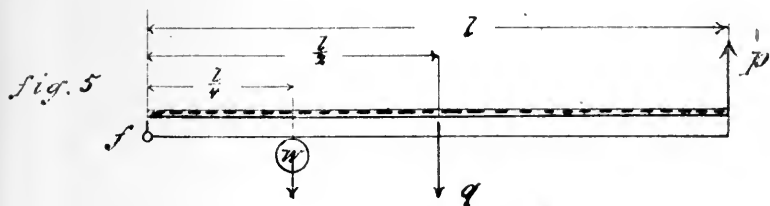
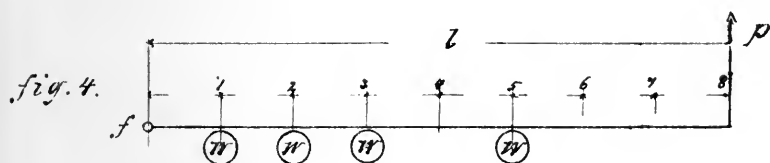
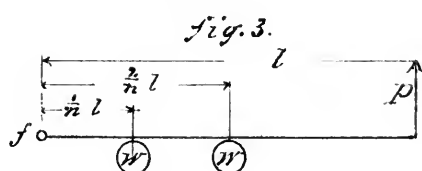
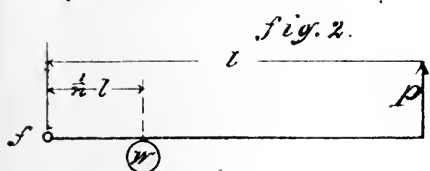
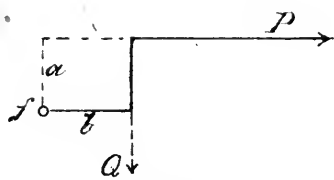


fig. 1<sup>c</sup>





In every triangle the sum of enclosed angles,

$$2 R. = 2 \times 90^\circ,$$

- 6.] so in the right angled triangle  $ABC$ , Fig. 6, the angles  $A$  and  $C$  together  $= 90^\circ = R$ , because angle  $B = 90^\circ$ .

In Trigonometry we say—

$$\frac{b}{c} = \text{sine } \alpha; \frac{b}{a} = \text{tangent } \alpha; \frac{c}{a} = \text{secant } \alpha.$$

$$\frac{a}{c} = \text{cosine } \alpha; \frac{a}{b} = \text{cotangent } \alpha; \frac{c}{b} = \text{cosecant } \alpha; \text{ or, contracted,}$$

sin., cos., tang. or tg., cotang. or cotg., sec. and cosec.

For a radius,  $AC$ , as a unit, the line  $AB$  simply is called sine; the central distance,  $BC$ , cosine; and  $BE$  the versed sine of the angle  $\alpha$ .

For certain angles  $\alpha$  the relation  $\frac{b}{c}, \frac{b}{a}, \frac{c}{a}$ , etc., have certain and distinct numerical values. (See Haslett's or Haswell's "Tables of natural sines, cosines, tangents and cotangents from 1 to 90 degrees.")

Each triangle,  $ABC, A_1BC$  (Fig. 7), consists of six members—*i. e.*, three sides and three angles, from which always three are dependent on the rest; therefore, when three out of these six members are known, we can construct, or with more exactness we can calculate, the others, provided one at least of the given parts is a side.

For the transformation of trigonometrical functions, short notices in the form of a table, also the numerical values (natural sin, cos, etc.) of the principal angles, may be serviceable, viz.:

$$\sin x = \frac{1}{\text{cosec } x} = \frac{\text{tang } x}{\sec x} = \sqrt{1 - \cos^2 x}.$$

$$\cos x = \frac{1}{\sec x} = \frac{\text{cotang } x}{\text{cosec } x} = \sqrt{1 - \sin^2 x}.$$

$$\text{tang } x = \frac{1}{\text{cotang } x} = \frac{\sin x}{\cos x} = \sqrt{\sec^2 x - 1}.$$

$$\text{cotang } x = \frac{1}{\text{tang } x} = \frac{\cos x}{\sin x} = \sqrt{\text{cosec}^2 x - 1}.$$

$$\sec x = \frac{1}{\cos x} = \frac{\operatorname{cosec} x}{\cotang x} = \sqrt{1 + \tan^2 x}.$$

$$\operatorname{cosec} x = \frac{1}{\sin x} = \frac{\sec x}{\tan x} = \sqrt{1 + \cotang^2 x}.$$

DEGREES.	SIN.	Cos.	TANG.	COTANG.
0	0	1	0	$\infty$
15	0,258	0,965	0,267	3,732
20	0,342	0,939	0,363	2,747
25	0,422	0,906	0,466	2,144
30	$\frac{1}{2} = 0,5$	$\frac{1}{2}\sqrt{3} = 0,866$	$\frac{1}{3}\sqrt{3} = 0,577$	$\sqrt{3} = 1,732$
40	0,642	0,766	0,839	1,191
45	$\frac{1}{2}\sqrt{2} = 0,707$	$\frac{1}{2}\sqrt{2} = 0,707$	1,00	1,00
50	0,766	0,642	1,191	0,839
60	$\frac{1}{2}\sqrt{3} = 0,866$	$\frac{1}{2} = 0,5$	$\sqrt{3} = 1,732$	$\frac{1}{3}\sqrt{3} = 0,577$
65	0,906	0,422	2,144	0,466
75	0,965	0,258	3,732	0,267
$R = 90$	+ 1	0	+ $\infty$	0
$2 R = 180$	0	- 1	0	- $\infty$
$3 R = 270$	- 1	0	- $\infty$	0
$4 R = 360$	0	+ 1	0	+ $\infty$

$$\sin (R - x) = + \cos x, \text{ and } \cos (R - x) = + \sin x.$$

$$\sin (R + x) = + \cos x, \text{ and } \cos (R + x) = - \sin x.$$

## II. SUSPENDED WEIGHTS AND THE RESULTING STRAINS.

Plate 2,] In Fig. 8<sup>b</sup>, when  $W = 5000$  lbs,  $ab = be = 10$ ,  
 Fig. 8<sup>a</sup>,]  $bc = 8$ , and  $ac = ce = 12,8$  feet; the vertical strain at  
 " 8<sup>b</sup>.]  $c$  on each string  $= \frac{W}{2} = \frac{5000}{2}$ .

And, further, the actual strain in the direction of the string,

$$p = q = \frac{W}{2} \cdot \frac{ac}{bc},$$

or 
$$p = q = \frac{5000}{2} \times \frac{12,8}{8} = 4000 \text{ lbs.}$$

All other information is given in Fig. 8<sup>b</sup>.

When a heavy body,  $ABCD$  (Fig. 8<sup>c</sup>), is suspended by two  
 8<sup>c</sup>.] oblique strings,  $DH$  and  $CH$ , in a vertical plane, a straight  
 line drawn through the intersection will pass through the  
 centre of gravity,  $G$ , of the body.

9.] For the force in the direction  $ad$ , represented by  $q$ , we find from Fig. 9,

$$gh = ab \cdot \frac{bd}{L} = ab \cdot \frac{W}{L};$$

$$W = gh + id = gh + q \cdot \cos \alpha;$$

$$W = ab \cdot \frac{W}{L} + q \cdot \frac{bd}{ad};$$

or 
$$q = W \cdot \left(1 - \frac{ab}{L}\right) = W \cdot \frac{L - ab}{L} \cdot \frac{ad}{bd};$$

i. e., 
$$q = W \cdot \frac{bc}{L} \cdot \frac{ad}{bd};$$

and in the same manner from similarity of triangles,

$$p = W \cdot \frac{ab}{L} \cdot \frac{cd}{bd}.$$

In the equation for  $q$  is  $W \cdot \frac{bc}{L}$ , the vertical strain at  $d$  for the string  $ad$ ; in the second equation is  $W \cdot \frac{ab}{L}$ , the vertical strain at  $d$  for the string  $cd$ ,—equal to the shearing strains  $V$  and  $V_1$  on the supports.

*Example.*—When, again,

$$W = 5000 \text{ lbs.}, L = 100 \text{ feet},$$

$$ab = 10', bc = 90', \text{ and } bd = 8',$$

$$ad = 12.84', \text{ and } cd = 90.35',$$

so 
$$p = 5000 \times \frac{10}{100} \times \frac{90.35}{8} = 5646 \text{ lbs.},$$

and 
$$q = 5000 \times \frac{90}{100} \times \frac{12.84}{8} = 7020 \text{ lbs.};$$

then the results for the horizontal strain  $x$  and the vertical strain  $V$  at the right support are—

$$x = p \cdot \frac{cb}{cd} = p \cdot \sin \beta, \text{ or } x = W \cdot \frac{ab}{L} \cdot \frac{bc}{bd},$$

and 
$$V = p \cdot \frac{bd}{cd} = p \cdot \cos \beta, \text{ or } V = W \cdot \frac{ab}{L};$$

thus 
$$x = 5000 \times \frac{10}{100} \times \frac{90}{8} = 5625 \text{ lbs.};$$

$$V = 5000 \times \frac{10}{100} = 500 \text{ lbs.}$$

The results for the horizontal strain  $x_1$  and the vertical strain  $V_1$  at the left support are—

$$x_1 = W \cdot \frac{bc}{L} \cdot \frac{ab}{bd},$$

and

$$V_1 = W \cdot \frac{bc}{L};$$

thus

$$x_1 = 5000 \times \frac{90}{100} \times \frac{10}{8} = 5625 \text{ lbs.,}$$

and

$$V_1 = 5000 \cdot \frac{90}{100} = 4500 \text{ lbs.};$$

therefore, also,

$$x = x_1,$$

for

$$W \cdot \frac{ab}{L} \cdot \frac{bc}{bd} = W \cdot \frac{bc}{L} \cdot \frac{ab}{bd}. \quad (\text{Fig. 17.})$$

10.] For Fig. 10, when  $W = 5000$  lbs.;  $ab$ ,  $ad$  and  $bd$  the same as before—

$$Y = W \cdot \frac{ad}{bd} = 5000 \times \frac{12.84}{8} = 8025 \text{ lbs.,}$$

and

$$Y_1 = W \cdot \frac{ab}{bd} = 5000 \times \frac{10}{8} = 6250 \text{ lbs.}$$

11.] In Fig. 12,

$$P : Q : R = \sin . cdb : \sin . adb : \sin . adc.$$

12.] In general, for every triangle,

$$y = x + z, \quad (\text{Fig. 12.})$$

and, as here,

$$x + y = z + m = R,$$

$$x + x + z = z + m,$$

or,

$$m = 2x.$$

Also, from similarity of triangles  $ABC$ ,  $ADC$  and  $DBC$ ,

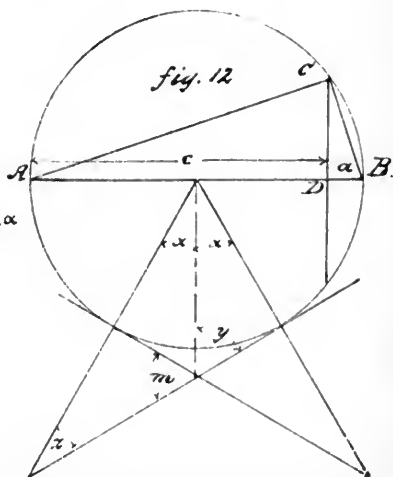
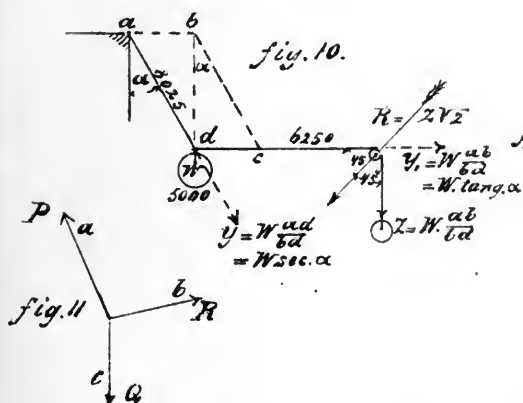
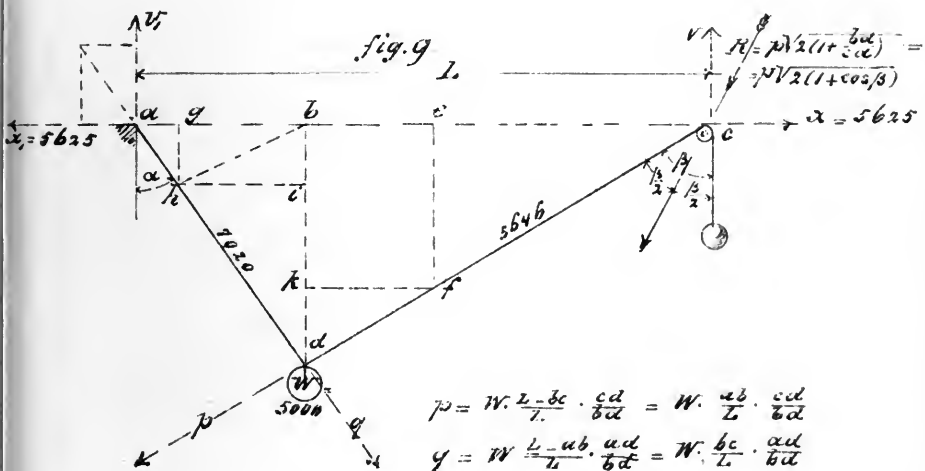
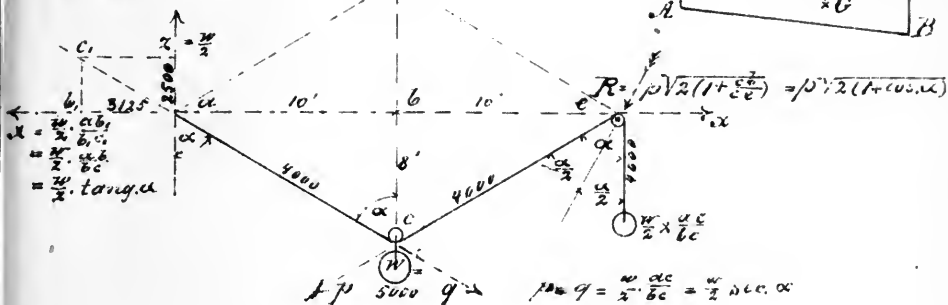
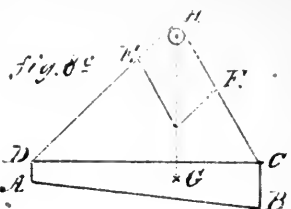
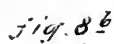
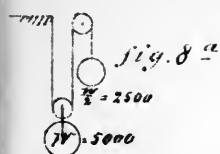
$$\frac{c}{b} = \frac{b}{a}, \quad \text{or } c = \frac{b^2}{a};$$

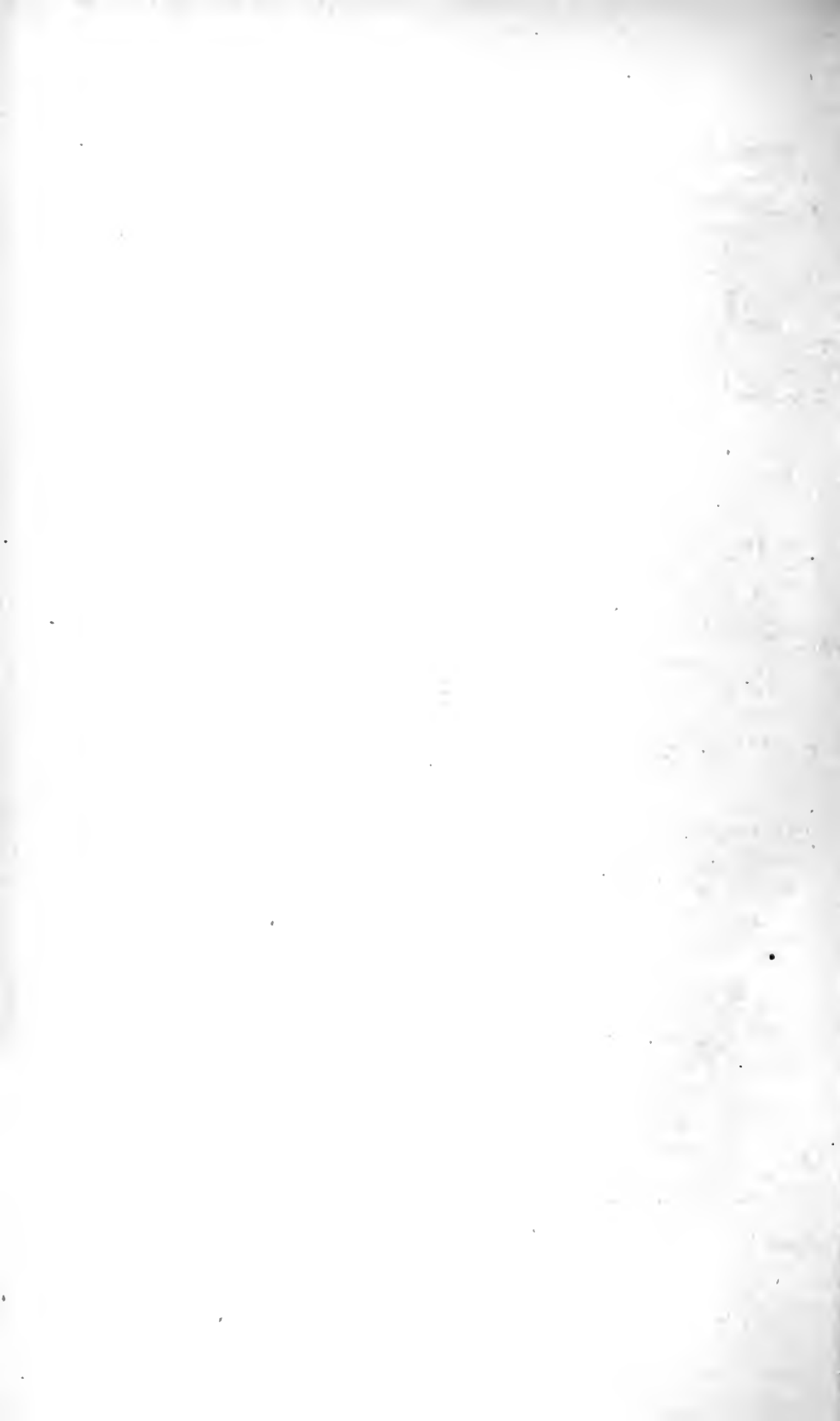
and as  $AB = c + a$ , the diameter  $= \frac{b^2}{a} + a$ ;

i. e., the diameter equals the square of one-half the chord divided by the height of the arc added to the height of the arc.

The height of the arc  $CB$  results from the chord  $CB$  in the same way.







Application in "Camber in Bridges," B, Sect. II. There, also, the geometrical rule,

$$\frac{\text{arc}}{\text{circumference}} = \frac{\text{angle at centre}}{360^\circ}.$$

[Plate 2—Figs. 8 to 12.]

### III. TRUSSES WITH SINGLE AND EQUALLY-DISTRIBUTED LOAD.

Plate 3,] A most frequent structure is the trussed beam (Fig. 13).

The post at the centre is called the king-post.

14.] The whole is a combined system, in which the horizontal beam, according to its stiffness, relieves the tie-rods from an aliquot amount of strain.

For the greatest exertion to which the tie-rods in the most unfavorable case could be exposed, we may use the result from Fig. 8<sup>b</sup>, under the supposition that the horizontal beam counteracts only the horizontal forces. (For instance, when butted at the centre.)

To compute the stress we have the following:

$$p = q = \frac{W}{2} \cdot \frac{ac}{bc} = \frac{W}{2} \cdot \sec \alpha,$$

for a single weight at centre.

*Example.*—The assumed weight = 20000 lbs.; between supports, 24 feet.

The length  $bc = 5,59'$ , and  $ac = 13,24$  (which can be measured near enough for most purposes from a skeleton);

$$p = q = \frac{W}{2} \cdot \frac{ac}{bc} = 10,000 \times \frac{13,24}{5,59} = 23,700 \text{ (approx.)}$$

The angle  $\alpha$  being in this case  $65^\circ$ , for a calculation, using the preceding tables,

$$p = q = \frac{W}{2} \cdot \sec \alpha = \frac{20000}{2} \times \frac{1}{\cos \alpha} = 10000 \times \frac{1}{0,422} = 23700,$$

$$bc = ab \cdot \tan 25^\circ = 12 \times 0,4663 = 5,595,$$

$$ac = ab \cdot \sec 25^\circ = ab \cdot \frac{1}{\cos 25^\circ} = 12 \times \frac{1}{0,906} = 13,24,$$

The vertical pressure in the king-post under the supposition before = 20,000 lbs.; at each support = 10,000 lbs.; and the compression in the horizontal beam,

$$H = \frac{W}{2} \cdot \frac{ab}{bc} = 10000 \times \frac{12}{5,59} = 21467 \text{ lbs.}$$

15<sup>a</sup>.] When in Fig. 15<sup>a</sup> the strains  $p$  or  $q$  and the angle  $\gamma$  are known, we find the resulting vertical strain,  $R$ , also by means of the parallelogram of forces, viz.,

$$R = \sqrt{p^2 + q^2 + 2p \cdot q \cdot \cos \gamma};$$

or, because in this case  $\alpha = \beta$ , therefore,  $p = q$ ;

also,  $\gamma = 2.65^\circ = 130^\circ$ , or  $= R + 40$ ,

and  $\cos(R + 40) = -\sin 40$  (see preceding table),

so  $R = \sqrt{2p^2 + 2p^2(-\sin 40)} = \sqrt{2p^2(1 - \sin 40)}$ ,

15<sup>b</sup>.]  $R = \sqrt{2 \times 23700^2 (1 - 0,642)} = 20000 \text{ lbs.}^*$

For a structure, Fig. 15<sup>b</sup>, reserved to the preceding one (15<sup>a</sup>), the numerical value of strains is quite the same, but of opposite character, provided the enclosed angles are the same.

If, as in Fig. 16, the load = 40000 lbs., equally distributed on the beam, then each support will sustain again one-half of the load; 16.] but the reaction,  $D$ , of each support will be only one-quarter of the load = 10000 lbs.; and for the same exertion a truss or beam, charged with an equally-distributed load, will sustain twice as much as when loaded with a single weight at the centre. (Comp. Fig. 14.)

The distribution of forces on supports and at the centre is explained by Fig. 16.

For an angle,  $\alpha = 63^\circ 26'$ , or, also,  $\beta = 26^\circ 34'$ ,

the depth of the truss being always equal to one-fourth of its length, for  $\text{tang} . 26^\circ 34' = 0,5$ .

Now,  $\frac{bc}{ab} = \text{tang} . \beta$ , or,  $bc = db . 0,5 = 12 \times 0,5 = 6$ ,

\* For the angle  $acd = \delta$  in Fig. 15<sup>b</sup>,

$$R = \sqrt{p^2 + q^2 + 2pq \cos \delta}, \quad \text{and for the angle } edS = \epsilon,$$

$$R = \sqrt{p_1^2 + p^2 - 2p_1 \cdot p \cdot \cos \epsilon}. \quad (\text{See Fig. 8}^b \text{ and Fig. 9.})$$





and (Fig. 14), the horizontal strain,

$$H = \frac{W}{2} \cdot \frac{12}{6} = \frac{20000}{2} \times \frac{12}{6}, \quad \text{or } H = 20000,$$

thus being in this case the same as the weight,  $W$ , at the centre.

The horizontal strain (thrust) and the strain on the oblique rods increase with the angle  $\alpha$ , thus being  $\infty$  for an angle  $\alpha = 90^\circ$ .

### SUSPENSION TRUSS BRIDGE.

We find a combination of trussing in the well-known "Suspension Truss" bridges, the principles for calculation of the strains being contained in the preceding.

The *Bollmann truss* forms a continuous system of independent trusses, in number equal to the number of vertical posts combined to a common top chord (stretcher).

Plate 4,] By Fig. 17 the dimensions of such a truss may be Fig. 17.] represented.

When for a single-track railroad-bridge the assumed load, including the weight of structure =  $1\frac{1}{2}$  tons = 3360 lbs. per lineal foot, or for one rib (single truss) = 1680 lbs. per lineal foot—i. e., for the given dimensions  $12 \times 1680 = 20160$  lbs. on each post, for which may be said in round figures 20000 lbs. =  $W$ , for calculation, then in Fig. 17, according to Fig. 9, the tension in the first rod nearest the abutment,

$$\text{Strain No. 1, rod} = W \cdot \frac{bF}{AF} \cdot \frac{Ak}{bk} = 20000 \times \frac{7}{8} \times \frac{15,6}{10} = 27300 \text{ lbs.},$$

the section of which for a value of iron = 10000 lbs. per square inch (five to six times security) = 2,73 square inches; thus, when two rods are applied, the size of each rod =  $1 \times 1\frac{3}{8}$ ".

$$\text{Strain No. 2, rod} = W \cdot \frac{cF}{AF} \cdot \frac{Al}{cl} = 20000 \times \frac{6}{8} \times \frac{26}{10} = 39000 \text{ lbs.}$$

Section = 3,9 sq. in., or 2 rods, each  $1 \times 2$ ".

$$\text{Strain No. 3, rod} = W \cdot \frac{dF}{AF} \cdot \frac{Am}{dm} = 20000 \times \frac{5}{8} \times \frac{37,3}{10} = 46625 \text{ lbs.}$$

Sect. = 4,66, or 2 rods, each  $1 \times 2\frac{3}{8}$ ".

$$\text{Strain No. 4, rod} = W \cdot \frac{eF}{AF} \cdot \frac{AN}{EN} = 20000 \times \frac{4}{8} \times \frac{49}{10} = 49000 \text{ lbs.}$$

Sect. = 4,90, or 2 rods, each  $1 \times 2\frac{1}{2}$ ".

$$\text{Strain No. 5, rod} = W \cdot \frac{fF}{AF'} \cdot \frac{Ao}{fo} = 20000 \times \frac{3}{8} \times \frac{60,8}{10} = 45600 \text{ lbs.}$$

$$\text{Sect.} = 4,56, \text{ or 2 rods, each } 1 \times 21''.$$

$$\text{Strain No. 6, rod} = W \cdot \frac{gF}{AF'} \cdot \frac{Ap}{gp} = 20000 \times \frac{2}{8} \times \frac{72,6}{10} = 36300 \text{ lbs.}$$

$$\text{Sect.} = 3,63, \text{ or 2 rods, each } 1 \times 17''.$$

$$\text{Strain No. 7, rod} = W \cdot \frac{hF}{AF'} \cdot \frac{Aq}{hq} = 20000 \times \frac{1}{8} \times \frac{84,6}{10} = 21150 \text{ lbs.}$$

$$\text{Sect.} = 2,11, \text{ or 2 rods, each } 1 \times 14''.$$

When for a partial load at a certain panel the exertion of a pair of suspenders is greater than for a distributed load in calculation, those rods would be strained more than to one-fifth or one-sixth of their ultimate strength. So, when a locomotive of 84000 lbs. weight rests at a certain panel on a wheel-base of 12 feet, to each of the four supporting posts would be transmitted one-fourth of its weight = 21000 lbs.—this differing very little from the calculation in the example. Additional rods (panel-rods) are applied, sustaining the main suspenders and at the same time the top chord, transmitting and distributing the weight on the posts, these being always in a state of compression equal to the weight on the post.

Without the panel-rods for an over-grade bridge (through bridge) there would be in the post no further compression than that produced by the weight of the top chord and appendages, leaving for a strong cambered truss (B, Sect. II.), in case of a partial load, the possibility of raising.

The following is the strain in panel-rods according to Fig. 8<sup>b</sup>:

$$\text{Strain} = \frac{W}{2} \cdot \frac{Er}{fr} = \frac{20000}{2} \times \frac{16}{10,5} = 15238 \text{ lbs.}$$

$$\text{Sect.} = 1,52, \text{ or 1 rod} = 1 \times 14''.$$

The influence of temperature upon the single systems of main suspenders (their length being different) is regulated by a link connection.

For the compressive strain in the top chord the rule for a girder, sustained at both ends and charged with an equally-distributed load, may be applied (see at the close of this chapter), then,



$$\frac{20000 \times \frac{7}{2} \times \frac{9.5}{4}}{10} = 168000.*$$

The compression in the top chord is the same all over.

For the result we have as momentum one-half of the entire weight on posts at one-fourth the length of truss as leverage,

$$\text{or} \quad \text{Mom.} = \frac{Q}{2} \times \frac{L}{4},$$

which, when divided by the depth of truss, gives the compression = 168000 lbs. as before.

For a single load,  $P$ , at the centre would be

$$\text{Mom.} = \frac{P}{2} \times \frac{L}{2},$$

which, when divided by the depth of truss, gives for the compression twice as much, or 336000 lbs.; but for an addition of the results of each single truss with its single load, according to  $x$  and  $x_1$  in Fig. 9, it would be

$$\text{Mom.} = \frac{P}{2} \times \frac{3L}{8},$$

this being one-half of the result for a single load,  $P$ , at the centre, added to one-half of the result for an equally-distributed load,  $Q$ .

18.] The *Fink truss* (Fig. 18) is different in principle.

Whilst in the Bollmann system there are as many independent trusses as there are posts, in the Fink all the trusses are dependent on each other and transfer the load toward the centre.

The centre post (king-post) has to sustain the compression of one-half of the entire load on the truss, including one-fourth of the weight of the rib, the main suspenders (tie-rods) depending again, as before, on the depth of the truss.

---

\* For a simple compressive strain an area of section of stretcher = 9 square inches would be sufficient (18000 lbs.—safe load for cast iron)—the actual dimensions to be taken by Hodgkinson's formula on the strength of hollow cast-iron pillars:

$$W = \text{breaking weight in tons} = 44.3 \times \frac{D^{3.6} - d^{3.6}}{l^{1.7}};$$

therefore, when for a pillar, the external diameter,  $D$ , in inches, and the length,  $l$ , in feet, are known; and for six times security, with the weight,  $W$ , multiplied by 6, we can define the internal diameter,  $d$ , consequently the thickness of metal.

The calculation of an example in its simplicity will give the best explanation.

Taking the same dimensions and the same load as in the calculation for the preceding (Fig. 17), according to Fig. 8<sup>b</sup> we have,

$$\text{Strain in } A.N \text{ or } IN = \frac{W}{2} \times \frac{AN}{EN};$$

$$\text{i.e.,} \quad \frac{80000}{2} \times \frac{49}{10} = 196000 \text{ lbs.,}$$

the section of which for a value of iron = 10000 lbs. per square inch = 19.6 square inches. Thus, when two rods are applied, the size of each =  $2 \times 5$  inches.

$$\text{Strain in } kc, Ak \text{ or } cm = \frac{20000}{2} \times \frac{13}{5} = 26000 \text{ lbs.}$$

Section of a single rod =  $1 \times 2\frac{1}{2}$  in. (full).

$$\text{Strain in } Al \text{ or } lE = \frac{40000}{2} \cdot \frac{26}{10} = 52000 \text{ lbs.}$$

Section of a single rod =  $2 \times 2\frac{1}{2}$  in., or  $1 \times 5$  in.

For a single locomotive (weight 84000 lbs.), resting at *cd* on a wheel-base of 12 feet, the vertical force for one post at *c* or *d* =

$$\frac{42000}{2} = 21000 \text{ lbs.} = W;$$

$$\text{then,} \quad \text{Strain in tie-rods} = \frac{21000}{2} \times \frac{13}{5} = 27300 \text{ lbs.};$$

so the size of rod *kc*, *Ak* or *cm* should be corrected to  $1 \times 2\frac{1}{2}$  in.

For the compressive strain on the top chord (stretcher), according to Fig. 14,

$$H = \frac{W}{2} \cdot \frac{AE}{EN},$$

and for a vertical strain  $W = 80000$  lbs. in the centre post, as before mentioned,

$$H = \frac{80000}{2} \times \frac{48}{10} = 192000 \text{ lbs. (compr.).}$$

In this truss, as in the Bollmann, the compression in the top chord is the same all over.

For this truss, when applied for an over-grade railroad-bridge, a safe longitudinal connection (bracing or tying) will be essential on account of the variable load.

fig. 17.

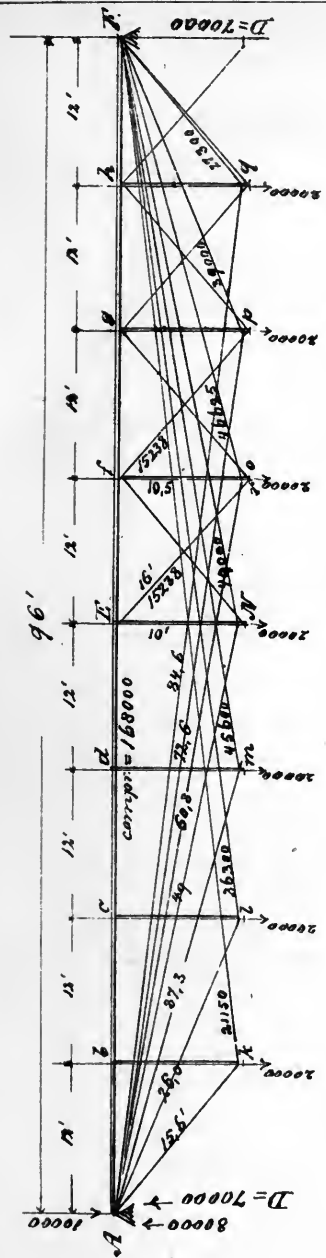


fig. 18.

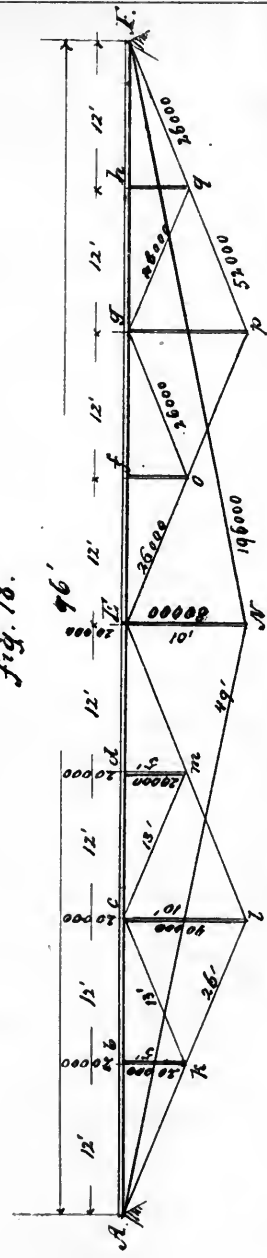
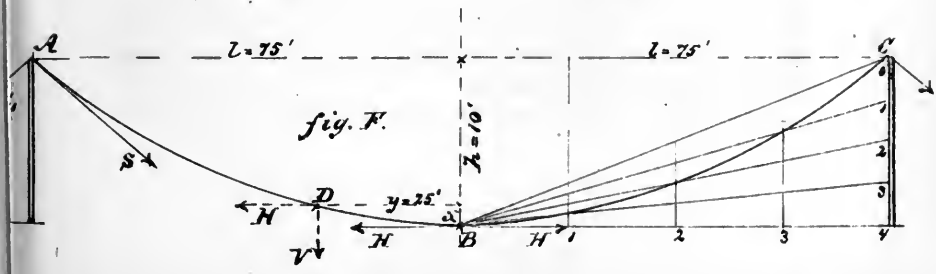


fig. F.





To the same category of bridges belongs the

### SUSPENSION BRIDGE,

though, in regard to mathematics, very different.

The curve formed by a chain or cable lies between the parabola and the catenary, and is very nearly an ellipse. The curve in a loaded state approaches the parabola; in an unloaded state, the catenary. (Weisbach, vol. II.)

In the following example the curve may be considered a parabola or the bridge in its loaded state.

The thesis is—

The vertical force at every point of the chain equals the weight on the chain from the point in consideration unto the vertex.

Plate 4,] So, when  $y$  in Fig. F = 25 feet and the length of  
Fig. F.] bridge = 150 feet,

Width = 4 feet;

load, 50 lbs. per square foot, or 200 lbs. per lineal foot;

maximum load =  $200 \times 150 = 30000$  lbs.;

the vertical force at  $D = 200 \times 25 = 5000$  lbs.

Further, the horizontal force at every point of the chain is equal, and therefore equal to the horizontal strain in the vertex.

Thus, when by  $p$  is represented the weight *pro unit* of horizontal projection = 200 lbs., for our example,

$$\text{I. } H = \frac{pl^2}{2h}, \text{ which is at the same time the horizontal force in } A \text{ and } C, \text{ to overturn the towers, and amounting here to } \frac{200 \times 75^2}{20} = 56250 \text{ lbs.}$$

$$\text{II. } S = \frac{pl}{2h} \sqrt{l^2 + 4h^2} = \frac{15000}{20} \times 77,6 = 58500 \text{ lbs.}$$

$$\text{III. } y^2 = \frac{l^2}{h} \cdot x.$$

The length,  $L$ , of chain results by the formula,

$$L = 2l + \frac{4}{3} \times \frac{h^2}{l} = 151,75.*$$

---

\* For more specifications I ought to refer to Weisbach and other authors.

For a trussed system with two posts (queen-posts), between supports 36 feet, and an assumed load = 30000 lbs., equally distributed, the distribution of forces on the bearings is denoted in Fig. 19, and for the calculation of strain, when compared with Fig. 10, we find for

$$Y = W \cdot \frac{ad}{bd};$$

$$Y = 10000 \times \frac{13,24}{5,59} = 23700 \text{ (approx.)};$$

and for

$$Y_1 = W \cdot \frac{ab}{bd};$$

$$Y_1 = 10000 \times \frac{12}{5,59} = 21467.$$

The compression on the vertical posts = 10000 lbs.; the vertical pressure on supports = 15000 lbs.; and, reduced by those 5000 lbs. directly sustained (comp. Fig. 16), the reactive force of supports, signified by  $D = 10000$  lbs.

Upon this structure, the *Method of Moments* being applied (see Preface), we suppose a section separated from the original by a cut, *st*.

Considering the forces acting upon such a section, we form the equation of equilibrium for a suitable point of rotation, by solution of which we find the strain in the member in question; and observe the rule, that, for a strain,  $Y$ , the point of rotation ought to be chosen in the intersection of  $x$  and  $z$ , making their lever = 0, when these are the members of the structure, separated by a cut, *st*, likewise as  $Y$ .

20.] But when by *st* only one member, excepting  $Y$ , is separated, we lay the point of rotation on the next joint, as, per example, for  $Y$  in  $b$ , Fig. 20.

$$Y \cdot 5,07 = 10000 \times 12,$$

$$\text{or, I., } 0 = -Y \cdot 5,07 + 10000 \times 12 \text{ (rotation round } b);$$

$$Y = \frac{10000 \times 12}{5,07} = + 23700;$$

and because in the following the form of equation always will be kept similar to I., the forces in their aim to turn to the left, like  $Y$  round  $b$ , will be signified by —, the same as a compressive strain; and the forces to the right, like the hands on a watch, or  $D$  round  $b$ , will be signified by +, the same as a tensile strain.

21.] According to this we have for  $Z$ , Fig. 21,

$$0 = Z \cdot 5.59 + D \cdot 12 \text{ (rot. } r. d),$$

$$Z = \frac{10000 \times 12}{5.59} = 21467,$$

and for  $Y_1$ , Fig. 22,

22.]  $0 = -Y_1 \cdot 5.59 + D \cdot 12 \text{ (rot. } r. b);$

$$Y_1 = \frac{10000 \times 12}{5.59} = 21467.$$

When a diagonal,  $s$ , sustains the parallelogram, so that by a cut,  $st$ , three members,  $Z_1$ ,  $Y_1$  and  $s$  are separated, we have for the definition of  $s$  the point of rotation, as before mentioned, in the intersection of  $Z_1$  and  $Y_1$ ; but  $Z_1$  and  $Y_1$  in their direction are parallel, and therefore without intersection at all. In this case (the same as for diagonals in girders with parallel top and bottom flanges) we  
23.] suppose a point of rotation,  $O$ , at any distance in the direction (axis)  $x$ , and find thus from Fig. 23, where  $x = \infty$ , or infinite—i. e., the lever of all forces, acting in a vertical direction upon the section  $= \infty$ .

$$0 = -s \cdot \infty \sin \varphi - D \cdot \infty + p \cdot \infty \text{ (rot. } r. O);$$

or, because  $\infty$  is a factor of each part,

$$0 = -s \cdot \sin \varphi - 10000 + 10000.$$

In this equation,  $s \cdot \sin \varphi$  (comp. Fig. 56 on semi-girders) is  
24.] the vertical component of  $s$  (Fig. 24), and acts right-angled to the axis,  $x$ , like  $D$  and  $p$ .

The angle  $\varphi$  for our example  $= 25^\circ$ ;

$$\sin \varphi = 0.422 \text{ (see table),}$$

and therefore  $0 = -s \times 0.422 - 10000 + 10000$ ,

or  $s = 0$ ,

showing that, as in Fig. 19, the diagonal,  $s$ , is without any strain and only useful for preventing dislocation. (Compare parabolic

25.] girders, to which this case is similar, because a parabola can be constructed through the sustaining points  $a$ ,  $d$ ,  $e$  and  $c$ , and therefore differs in this from Figs. 25 and 63.)

26.] For a reversed structure (Fig. 26) the strains will be the same, but of reversed signs.

In the following calculations of roofs and bridges it will be shown

that the *Method of Moments* is thoroughly applicable, leading directly and in the most comprehensive manner to distinct results; but for a preliminary estimate of strain in the top and bottom chords at the centre of the structure the most simple way to define this strain may be stated by the following:

As the flanged girder in Fig. 27, charged with an equally-distributed load,  $Q$ , will be exposed at its centre to the same  
 27.] exertion as the girder in Fig. 28, fixed at the centre, the  
 28.] moments will be for both, when  $V$  = depth of girder and  $l$  = length (the load being equally distributed).

$$\text{Mom} = \frac{Q}{2} \cdot \frac{l}{4} = V \cdot x \text{ (rot. } r \cdot o \text{);}$$

$$\frac{\frac{Q}{2} \cdot \frac{l}{4}}{V} = \frac{\frac{1}{2} Q \cdot l}{V} = \text{compression or tension in flanges;}$$

so  $Q = 30000 \text{ lbs.}; V = 5.59'; \text{ and } l = 36'.$

$$\text{Mom} = \frac{30000}{2} \times \frac{36}{4} = 135000 = V \cdot x,$$

and  $\frac{135000}{5.59} = 24150 \text{ lbs., the strain in the chords.}$

It is to be observed that the result is rather too high when applied upon a truss with few panels, as in Fig. 26, on account of the reactive pressure of the support, diminished by the partition of the direct load on this place.

On account of its being a very convenient method we recommend it; and in the following bridge skeletons we refer to it very frequently. (See D, Example I., and Sect II., note.)

29.] For a girder charged with a single weight at the centre  
 (Fig. 29), we make a comparison with Fig. 30, and find for both

$$\text{Mom} = \frac{P}{2} \cdot \frac{l}{2} = V \cdot x = \frac{1}{4} P \cdot l,$$

30.] and  $\frac{\frac{1}{4} P \cdot l}{V} = \text{horizontal strain;}$

i. e., compression or tension in the top or bottom chords, the formation of moments for a point of rotation,  $o$ , being very comprehensive.

When

$$P = 15000 \text{ lbs.,}$$







but  $V = 5,59$ , and  $l = 36$  (as before),

so the  $\text{Mom} = \frac{15000}{2} \times \frac{36}{2} = 135000$ ,

and  $\frac{\frac{15000}{2} \times \frac{36}{2}}{5,59} = 24150$  lbs., the strain in flanges;

showing that, for the same exertion, a beam loaded with a single weight,  $P$ , at the centre can bear only one-half of an equally-distributed load,  $Q$ .

[Plates 3, 4 and 5—embracing Figs. 13 to 30.]

## B. ROOF CONSTRUCTION.

For small and not complicated roofs, experience is a common and in general, also, a sufficient guide. But experience is very limited, and not every constructor has opportunity and time to acquire it.

The true and acceptable guide for a safe practice will always be the calculation; and since, especially for complicated and more extensive combinations, the application of mechanical science has become unavoidable, the following compendium, leading from the simplest to the most complicated structures, will give for almost every purpose sufficient information.

By construction, when  $EG$  represents the weight at the centre of gravity,  $G$  (Fig. 31<sup>a</sup>), the body will be at rest when Plate 6, Fig. 31<sup>a</sup>.] the plane  $DF$  is right-angled to the line  $DE$ ;  $CE$  being horizontal—i. e., right-angled to the vertical line  $EG$ .

Let  $EG$  be an assumed length, then in the parallelogram of forces the intensity of  $EK$  and  $EH$  is measured in proportion by the same rule.

For an angle,  $\beta = 25^\circ$  of a rafter with the horizontal line 31<sup>b</sup>.] (Fig. 31<sup>b</sup>—similar to Fig. 16 reversed) leaning with the top end against a wall, the heel at  $A$  being morticed; we then have

$$\frac{cb}{ca} = \sin \beta = \frac{5,59}{13,24} = 0,422;$$

$$\sin^2 \beta = 0,17;$$

$$\sin 2 \beta = \sin 50^\circ = 0,766;$$

$$\frac{ab}{ac} = \cos \beta = \frac{12}{13.24} = 0.906;$$

$$\cos^2 \beta = 0.82.$$

When  $W$  is an equally-distributed load of 20000 lbs., then

$$H = H_1 = \frac{W}{2} \times \frac{d}{h} = \frac{20000}{2} \times \frac{12}{5.59} = 21467 \text{ lbs.}$$

The vertical force,  $V$ , at the top of the rafter = 0, and the vertical pressure  $V_2$  of the heel = 20000 lbs., or equal to the entire load.

Also the vertical force,  $V_1$  at the centre = 20000 lbs.

The pressure in the rafter itself (compression) =

$$\frac{W}{2} \times \frac{l}{h} = 10000 \times \frac{13.24}{5.59} = 23685 \text{ (23700 lbs.)}.$$

The entire pressure,  $R$ , of rafter toward the support,

$$R = \sqrt{V_2^2 + H_1^2} = 29300 \text{ lbs.}$$

Its direction can be constructed in making  $K = 2h = 11.18$  feet,  $H_1$  and  $V_2$  forming the sides of the parallelogram.

When  $P = 10000$  lbs., a single weight at centre of rafter,

$$H = H_1 = \frac{P}{2} \cdot \frac{d}{h} = 10733;$$

$$V = 0,$$

and

$$V_2 = V_1 = 10000 \text{ lbs.}$$

When in Fig. 31<sup>e</sup>, by  $FM$  the weight of the body  $ABCD$  is represented, then  $FN$ , the force toward the wall, results in the horizontal and vertical forces  $CH$  and  $CV$ .

$FL$ , the force acting perpendicular to the plane  $BI$ , in the direction  $BF$ .

$G$ , the centre of gravity.

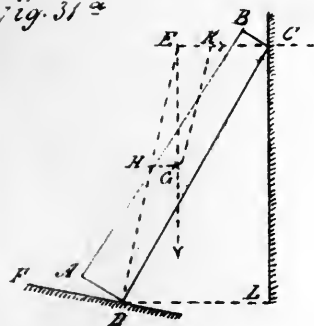
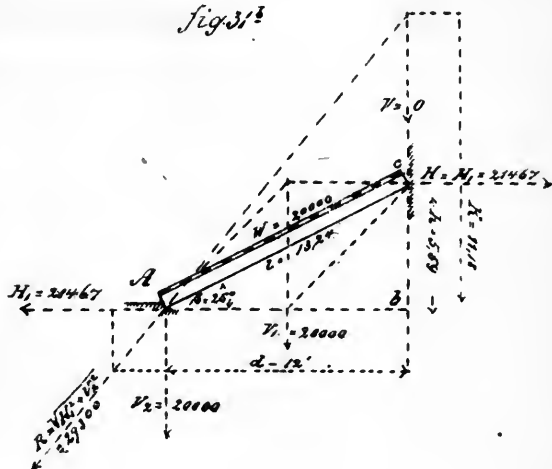
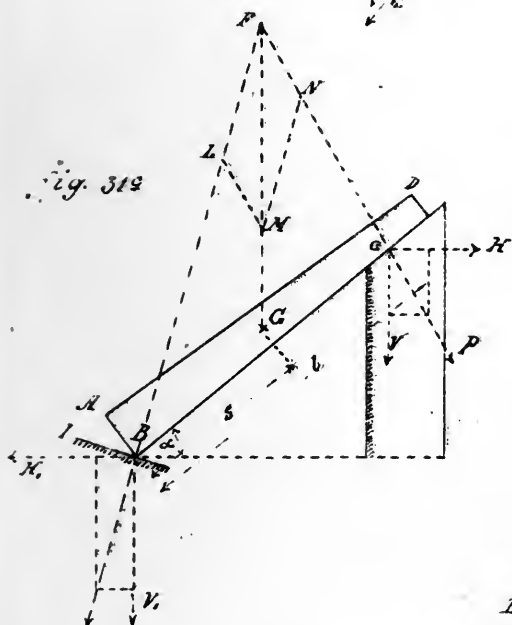
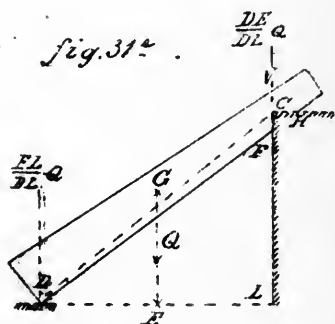
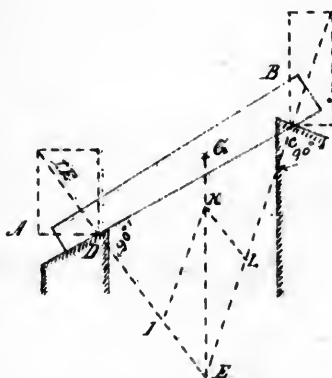
$GF$ , vertical.

$CF \perp CB$ , or  $\angle FCB = 90^\circ$ .

$BI \perp FB$ , then  $BI$  is the direction of the plane required to make the body at rest.

Also 
$$FN = P = \frac{s}{l} G \cos \alpha;$$

$$H = P \sin \alpha = \frac{s}{l} G \sin 2 \alpha.$$

fig. 31<sup>a</sup>fig. 31<sup>b</sup>fig. 31<sup>c</sup>fig. 31<sup>d</sup>fig. 31<sup>e</sup>



31<sup>a</sup>.] Let the sloping body  $ABCD$  (Fig. 31<sup>a</sup>) be supported by a wall at its lower end,  $D$ , which coincides with the surface of the body;

Let  $G$  be again the centre of gravity;

It is required to cut a notch out of the body at the upper end,  $C$ , so that it may rest upon the top of a wall which is made to fit the notch.

Make  $GE$  vertical;

From  $D$  draw  $DE \perp$  to  $CD$ ;

Join  $EC$ , and draw  $CF$  at right angles to it; then the notch at  $C$  being cut, the body  $ABCD$  will be at rest.

31<sup>a</sup>.] A body,  $ABCD$ , resting on supports (Fig. 31<sup>a</sup>), will only produce the vertical strains  $\frac{DE}{DL} \cdot Q$  and  $\frac{EL}{DL} \cdot Q$  at the supports.

Plate 7,]  
Fig. 32.] For Figs. 32, 33 and 34 we have, again,

$$\frac{bc}{ac} = \sin \beta; \frac{ab}{ac} = \cos \beta; \frac{bc}{ab} = \tan \beta; \frac{ab}{bc} = \cot \beta;$$

$$\sin 2\beta = \sin 50^\circ = 0,766;$$

and when upon each rafter  $W = 20000$  lbs., equally distributed, we have for Fig. 32,

$$H = H_1 = \frac{W}{2} \cdot \frac{d}{h} = \frac{W}{2} \cdot \cot \beta = 21467 \text{ lbs.}$$

$$\text{The compression in the rafter} = \frac{W}{2} \cdot \frac{l}{h} = 23685 \text{ lbs.,}$$

and, again,  $R = \sqrt{H_1^2 + V_2^2} = 29300 \text{ lbs.}$

For an angle  $\beta = 26^\circ 34'$ ; the horizontal thrust will = 20000 lbs.—i. e., the same as the entire weight. (Comp. Fig. 16.)

33.] For Fig. 33 is, as the rafter in a vertical direction, sustained on the top,

$$H = H_1 = \frac{W}{4} \cdot \sin 2\beta = 5000 \times 0,766 \times 3830;$$

$$V = \frac{W}{2} \cdot \cos^2 \beta = 10000 \times 0,82 = 8200;$$

$$V_2 = \frac{W}{2} (1 + \sin^2 \beta) = 10000 (1 + 0,17) = 11700;$$

and the compression in the rafter,

$$\frac{W}{2} \cdot \sin \beta = 10000 \times 0,422 = 4220 \text{ lbs.}$$

For Fig. 34, when the rafter is sustained at the top by a vertical post,

$$H = H_1 = \frac{W}{4} \cdot \sin 2\beta = 3830;$$

$$34.] \quad V = W \cos^2 \beta = 20000 \times 0,82 = 16400;$$

$$V_2 = \frac{W}{2} (1 + \sin^2 \beta) = 10000 (1 + 0,17) = 11700;$$

and the compression in the rafter =

$$\frac{W}{2} \cdot \sin \beta = 4220 \text{ lbs.}$$

In the cases in Figs. 33 and 34 the post relieves the tie-rod or (as here, in the absence of a tie) the wall from a part of the thrust of the rafters, and compared with the truss in the preceding we see that the king-post acts in a different way.

The different combinations of this single hanging-and-thrust construction may be disregarded, and by the following calculations the method of moments thoroughly applied.

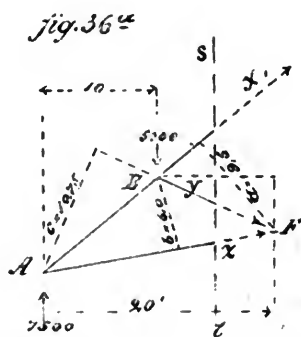
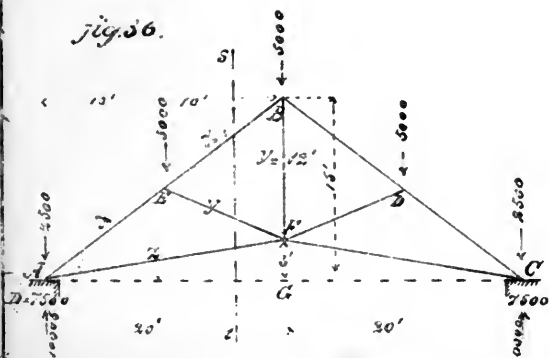
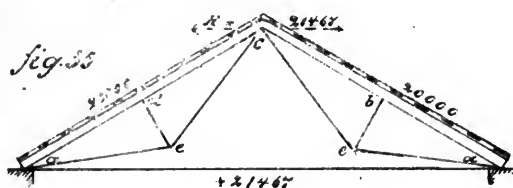
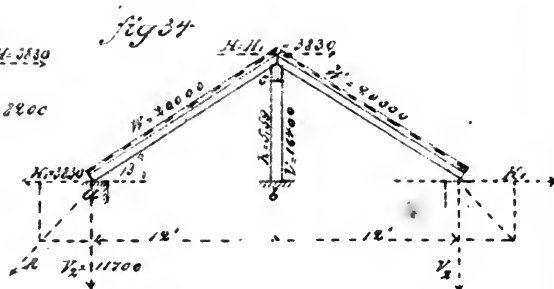
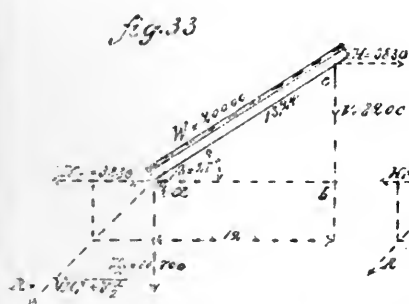
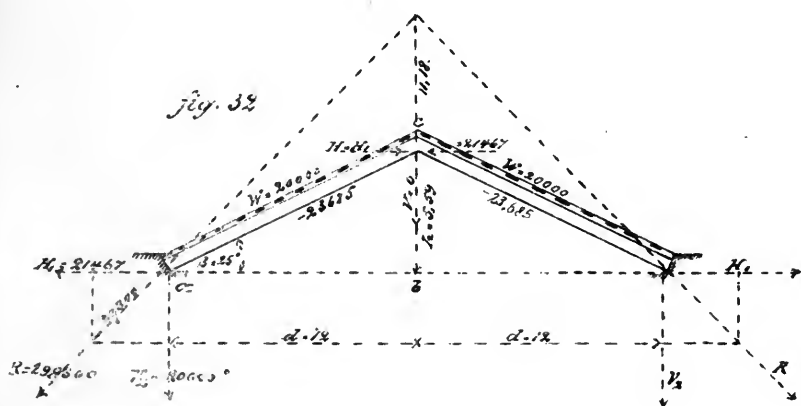
A rafter being constructed in this way (Fig. 35), without connection between the point *e* and the horizontal tie-rod *aa*, there are two different systems, that of a trussed beam, *acc*, similar to Fig. 16, 35.] and that of a single triangle like Fig. 32, and it is as there for the same angle,  $\beta$ , and a load = 20000 lbs. upon each rafter; the horizontal thrust, *H*, at the top, as also the tension in the horizontal tie-rod = 21467 lbs. The trussed rafter is understood to be calculated like Fig. 16 in combination with Fig. 31<sup>b</sup>.

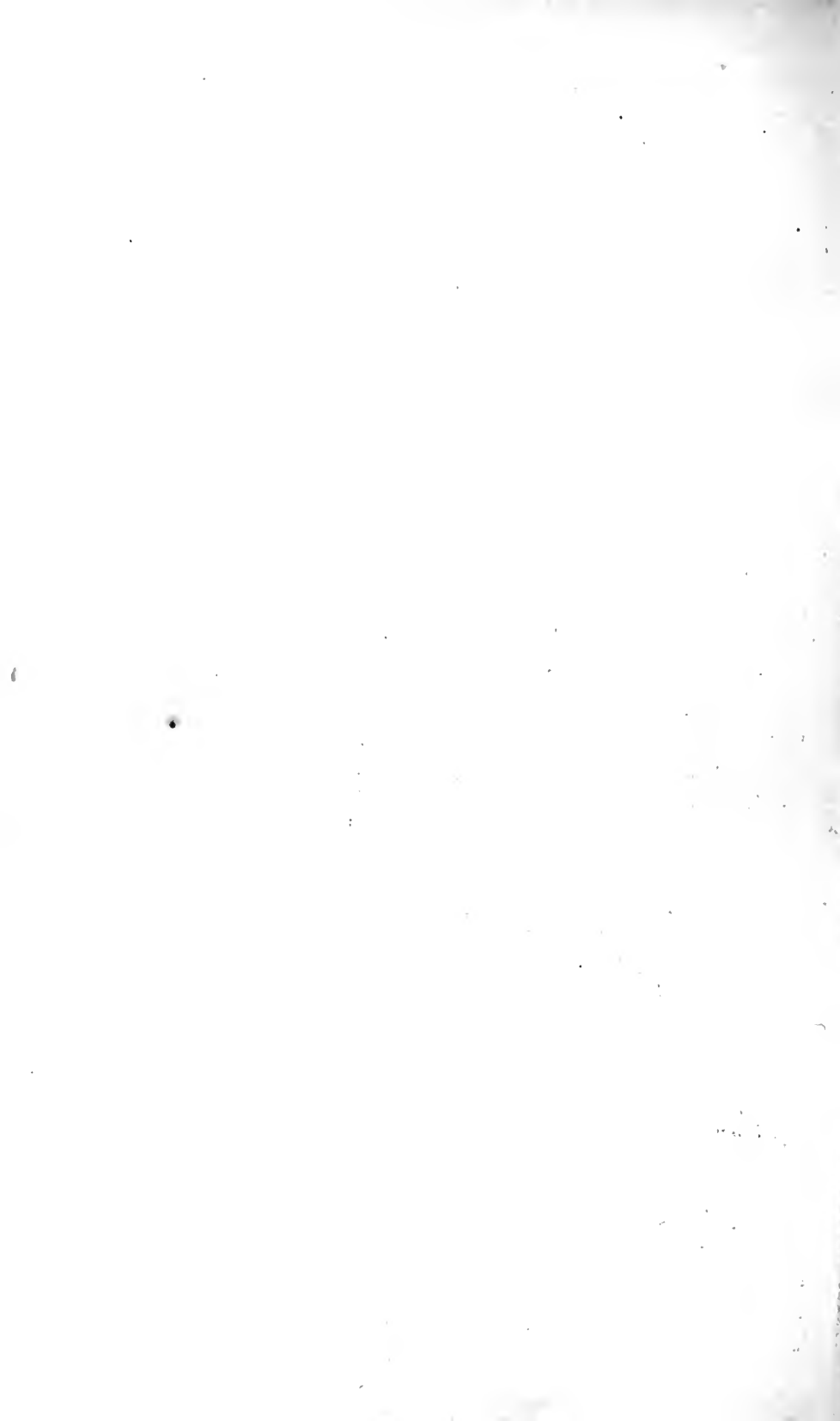
When the weight of structure, snow and wind-pressure upon a 36.] roof (Fig. 36), for one square foot of horizontal projection, in all = 50 lbs., and the width between the supports or *AC* = 40 feet, the distance of rafters = 10 feet, then 20000 lbs. is the entire load, or 10000 lbs. upon each rafter, supported at *A*, *B*, *C*, *D* and *E*.

The pressure of one-half of the weight, or 10000 lbs., on the supports is counteracted by the direct load of 2500 lbs. It is therefore the reacting force, *D*, only 7500 lbs. (See Howe Truss, Sect. I., D.)

For a section separated by *st* we can define at once the strains in







$z$ ,  $y$  and  $x_1$ , so for  $x_1$ , considering the forces acting upon this section and the point of rotation in the intersection of  $y$  and  $z$  or  $F$ . (Fig. 36<sup>a</sup>.)

$$36^a.] \quad 0 = x_1 \cdot a + D \cdot 20 - 5000 \times 10.$$

(Comp. Fig. 20, Equat. I.)

The arm or lever,  $a$ , can be measured near enough from a skeleton = 9,6'.

Besides, for the calculation of  $a$  we have for the angle  $ABG$  (Fig. 36),

$$AG = GB \cdot \text{tang} < ABG,$$

$$\text{or} \quad \text{tang} \cdot ABG = \frac{AG}{GB} = \frac{20}{15} = \frac{4}{3} = 1,333;$$

$$\text{i. e.,} \quad < ABG = 53^\circ 7', \text{ and } \sin 53^\circ 7' = 0,8;$$

$$a = BF \sin < ABG = 12 \times 0,8 = 9,6;$$

$$\text{therefore} \quad 0 = x_1 \cdot 9,6 + 7500 \times 20 - 5000 \times 10;$$

$$x_1 = - \frac{100000}{9,6} = -10412 \text{ lbs.}$$

For  $z$  (rot.  $r$ .  $E$ , Fig. 36<sup>a</sup>),

$$0 = -z \cdot 6 + 7500 \times 10,$$

$$\text{or} \quad z = + \frac{75000}{6} = +12500;$$

and for  $y$  (rot.  $r$ .  $A$ , Fig. 36<sup>a</sup>),

$$0 = y \cdot c + 5000 \cdot 10;$$

$$0 = y \cdot 10,75 + 50000,$$

$$\text{or} \quad y = - \frac{50000}{10,75} = -4650.$$

Plate 8, ] For the strain in  $x$  (rot.  $r$ .  $F$ , Fig. 36<sup>b</sup>) is,  
Fig. 36<sup>b</sup>.]

$$0 = x \cdot 9,6 + 7500 \times 20,$$

$$\text{or} \quad x = - \frac{150000}{9,6} = -15625.$$

In regard to the vertical  $V$ , we use for its definition the strain of the joining brace,  $x_1 = -10412$ , and make  $st$  a curved line; then we have, for a rot.  $r$ .  $D$  (Fig. 36<sup>b</sup>),

$$0 = -V \cdot 10 - (-10412) \cdot 10,9,$$

$$\text{or} \quad 0 = -V \cdot 10 + 113490;$$

i. e., 
$$V = + \frac{113490}{10} = + 11349.$$

37.] The results are combined in Fig. 37.

For Fig. 38, the entire load (equally distributed) again being 20000 lbs., the depth 15', and between the supports 40'.

38.] When here the cut  $st$  separates the line  $x_1y_1z_1$ , we have for  $x_1$  (rot. in the intersection of  $y_1z_1$ , or  $F$ , Fig. 39),

$$0 = x_1 \cdot 9,1 - 5000 \times 5\frac{1}{2} + 7500 \times 15\frac{1}{2};$$

39.] 
$$x_1 = - \frac{88750}{9,1} = 9752.$$

For  $y_1$  (rot.  $r. A$ ),  $0 = -y_1 \cdot 15 + 5000 \times 10$ ,

or 
$$y_1 = + \frac{50000}{15} = + 3,333;$$

and for  $z_1$  (rot.  $r. C$ ),

$$0 = -z_1 \cdot 15 - 5000 \times 10 = 7500 \times 20;$$

$$z_1 = + 6,666.$$

40.] For a section,  $st$ , through  $x$  and  $z$ , we have for  $x$  (Fig. 40),

$$0 = x \cdot 9,1 + 7500 \times 15\frac{1}{2} \text{ (rot. } r. F \text{)};$$

$$x = - \frac{116250}{9,1} = - 12774;$$

and for  $z$  (rot.  $r. D$ ),

$$0 = -z \cdot 7,4 + 7500 \times 10;$$

or 
$$z = \frac{75000}{7,4} = 10135.$$

For  $y$  (rot.  $r. A$ ) is,  $0 = y \cdot 12,5 + 5000 \times 10$ ;

$$y = - \frac{50000}{12,5} = - 4000.$$

41.] The results combined in Fig. 41.

42.] When the figure before is changed in the depth, like Fig. 42, we have the following equation:

$$0 = x_1 \cdot 5,8 - 5000 \times 3,25 + 7500 \times 13,25 \text{ (rot. } r. F, \text{ Fig. 43)};$$

$$x_1 = - \frac{83125}{5,8} = - 14332.$$

43.] For the definition of  $y_1$ , the intersection of  $x_1$  and  $z_1$  will be in  $G$ , and it is for  $G$  as rotation,

$$0 = -y_1 \cdot 8,25 + 5000 \times 6 + 7500 \times 4; \quad (\text{Fig. 43.})$$

fig. 36:

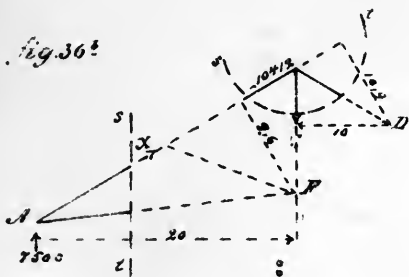
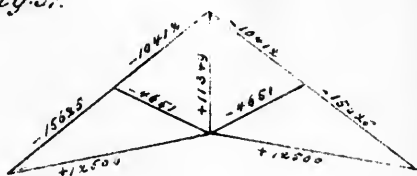
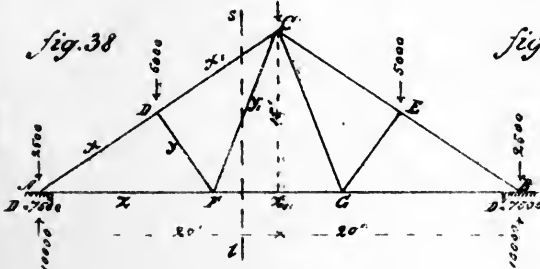


fig. 37.



*fig. 38*



*fig. 39*

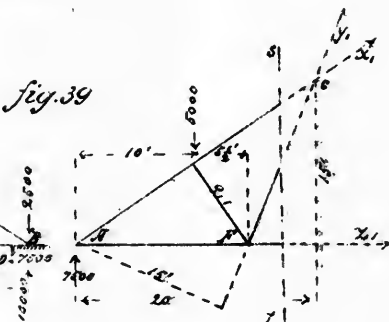


fig. 40

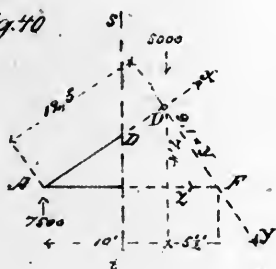
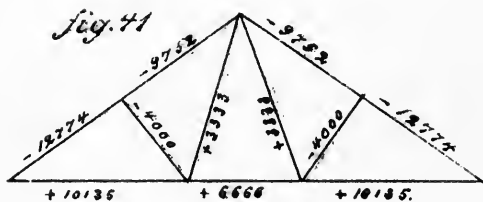
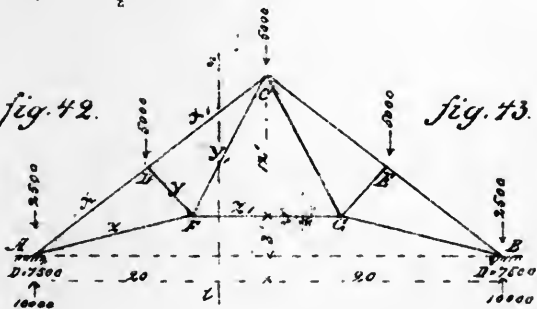


fig. 41



*fig. 42.*



*fig. 73.*

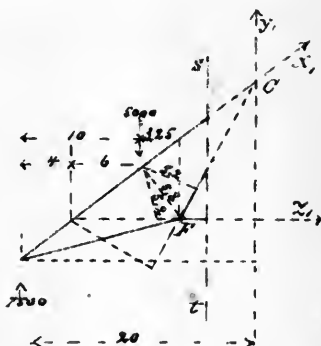


Fig. 14.

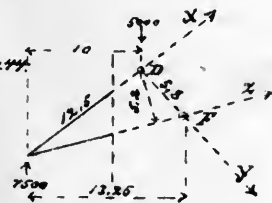
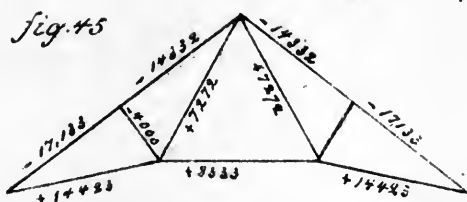


fig. 45





$$y_1 = + \frac{60000}{8,25} = 7272.$$

For  $z_1$  (rot.  $r. C$ ) we have

$$0 = -z_1 \cdot 12 - 5000 \times 10 + 7500 \times 20;$$

$$z_1 = + \frac{100000}{12} = + 8333.$$

44.] For a section,  $st$ , through  $x$  and  $z$  (Fig. 44), it is

$$0 = x \cdot 5,8 + 7500 \times 13,25 \text{ (rot. } r. F);$$

$$x = - \frac{993750}{5,8} = - 17133;$$

and  $0 = -z \cdot 5,2 + 7500 \times 10 \text{ (rot. } r. D);$

$$z = \frac{75000}{5,2} = + 14423;$$

and for  $y$ ,  $0 = y \cdot 12,5 + 5000 \times 10 \text{ (rot. } r. A);$

$$y = - \frac{50000}{12,5} = - 4000.$$

45.] The results combined in Fig. 45.

Plate 9,] For the definition of  $X$  in Fig. 46, the point of rotation  
Fig. 46.] in  $E$ , or in the intersection of  $Y$  and  $Z$ , will be from  
Fig 47.

$$47.] \quad 0 = X \cdot x - P \cdot CE + D \cdot AE;$$

$$\text{or} \quad X = \frac{P \cdot CE - D \cdot AE}{x}.$$

For  $Y$  we choose  $A$ , or the intersection of  $X$  and  $Z$ , as the point of rotation, and the equation will be

$$0 = -Y \cdot y + P \cdot AC + Q \cdot AE,$$

$$\text{or} \quad Y = \frac{P \cdot AC + Q \cdot AE}{y},$$

and in the same way for  $Z$ , rot.  $r. H$ .

$$0 = -Z \cdot z - Q \cdot EL - P \cdot CL + D \cdot AL,$$

$$\text{or} \quad Z = \frac{-Q \cdot EL - P \cdot CL + D \cdot AL}{z}.$$

It will not be necessary to show, by repetition of the foregoing, the equations for the other parts of the structure.

48.] In more complicated systems (Fig. 48), it may happen that by a cut,  $st$  (which can be made curved as well as straight), different braces or rods are spared, like  $FG$ ,  $DG$  and  $DE$ .

In this case it is possible to come to a direct result when  $st$  only can be laid so that all the braces or rods cut by  $st$  meet at one point, except that one whose strain is in question.

49.] So for the strain  $V$  in  $FG$  (rot.  $r$ .  $H$ , Fig. 49),

$$0 = -V.FH - R.r;$$

$$V = -\frac{R.r}{FH}.$$

50.] In the same manner the strain  $U$  in  $DG$  (rot.  $r$ .  $H$ , Fig. 50),

$$0 = U.u - R.r;$$

$$U = \frac{R.r}{u};$$

thus we find also the strain in  $KT$  and  $LT$ .

51.] Being by the foregoing in possession of a value for  $U$  in  $DG$ , we find for the strain  $X$  in  $DE$ ,  $Y$  in  $DE$ , and  $Z$  in  $CE$  the following equations from Fig. 51:

$$0 = X.DE + U.v - Q.NO - P.MO + W.AO \text{ (rot. } r.E);$$

$$0 = Y.AD + U.l + Q.AN + P.AM \text{ (rot. } r.A);$$

$$0 = -Z.z + W.AN - P.MN \text{ (rot. } r.D);$$

each one enabling us to obtain a direct result for the strain in question.

Plate 10,] For a roof (Fig. 52), the weight of which, 11,3 lbs. Fig. 52.] per square foot of its horizontal plan, may be calculated 20 lbs. for wind pressure and snow, making together 31,3 lbs. per square foot.

The distance of rafters being  $15\frac{1}{2}$  feet, the width, 100 feet, makes for each rafter  $15\frac{1}{2} \times 100 \times 31,3 = 48000$  lbs. (approx.).

The load at each apex, therefore, will be  $\frac{48000}{8} = 6000$  lbs., the

distribution of which is shown by the skeleton.

For the reactive force on the supports is again

$$D = 24000 - 3000, \quad \text{or } D = 21000 \text{ lbs.}$$

There are, in all, seven times 6000 lbs. acting downward, and twice 21000 lbs. acting vertically upward upon the system.



fig. 46

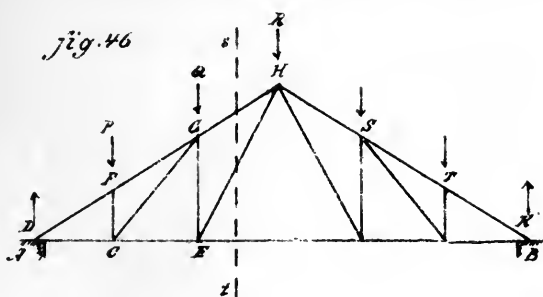


fig. 47

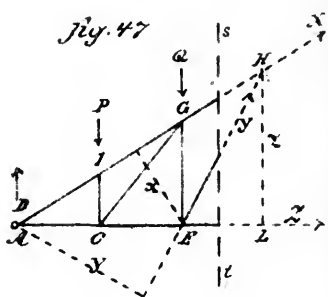


fig. 48

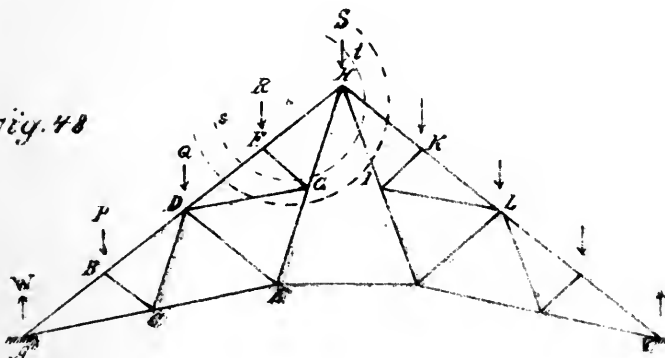


fig. 49



fig. 50

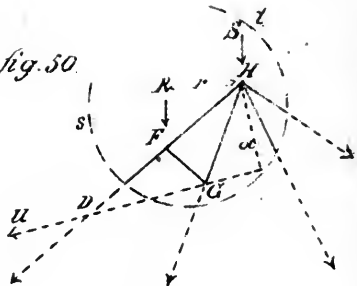
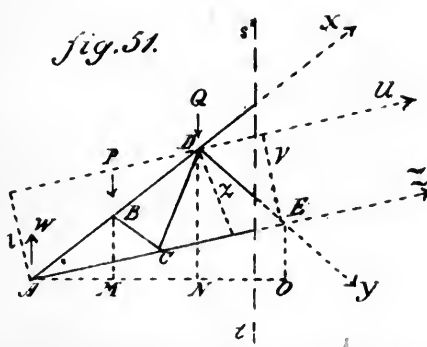
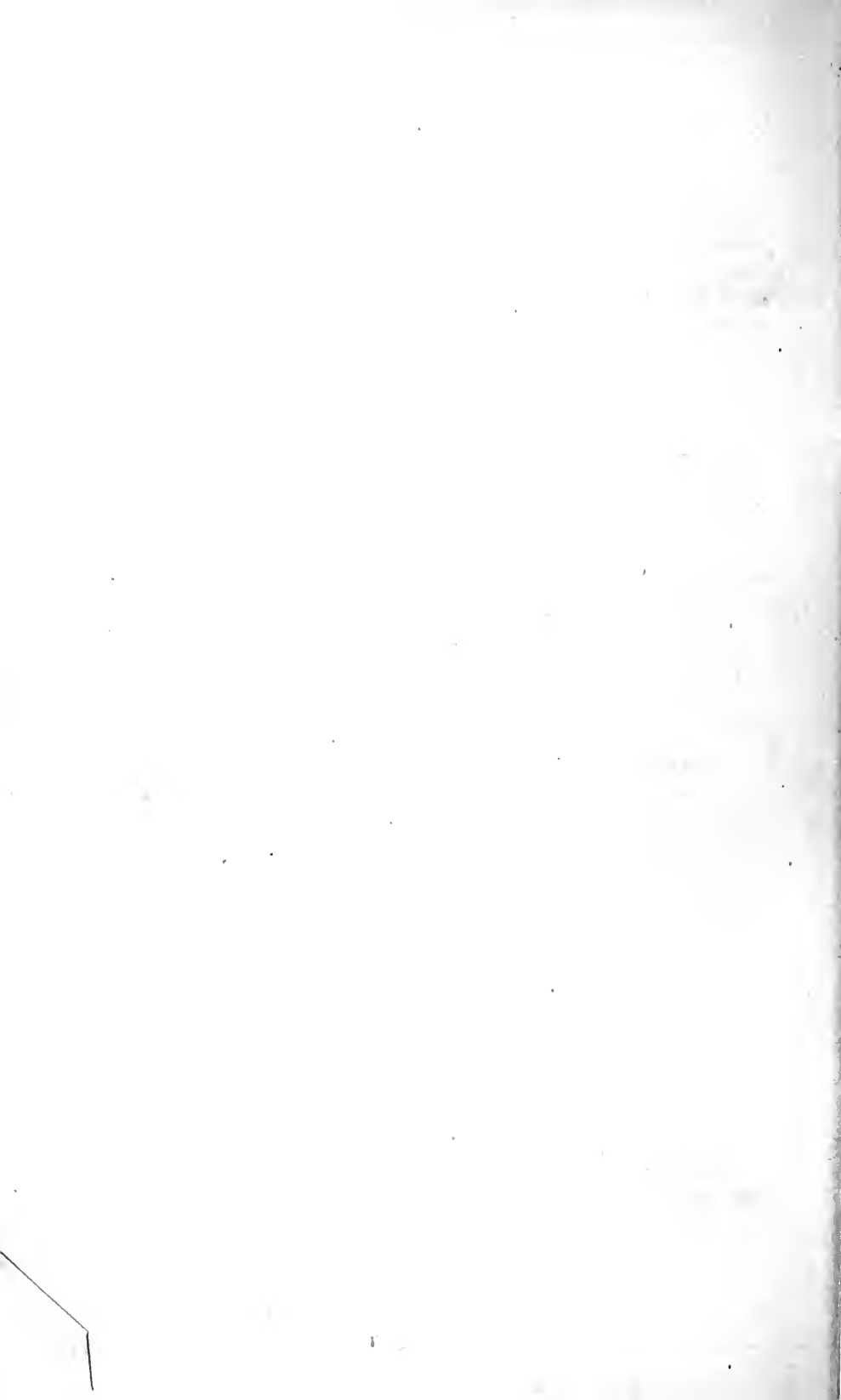


fig. 51





53.] The section,  $A, s, t$  (Fig. 53), kept in equilibrium by the replaced forces,  $x, y$  and  $z$ , may be regarded first as a lever with the fulcrum at  $D$ ; then the strain in  $x$  for the middle section is

$$0 = x \cdot 18,6 + 21000 \times 50 - 6000 \times 12,5 - 6000 \times 25 - 6000 \times 37,5,$$

$$\text{or} \quad x = 32300 \text{ lbs.};$$

and in  $y$ , when  $A$  is the point of rotation,

$$0 = y \cdot 38,4 + 6000 \times 12,5 + 6000 \times 25 + 6000 \times 37,5 \text{ (rot. } A);$$

$$y = -11700 \text{ lbs.},$$

and

$$0 = -z \cdot 15 + 21000 \times 37,5 - 6000 \times 12,5 - 6000 \times 25 \text{ (rot. } r. E),$$

$$Z = +37500 \text{ lbs.}$$

54.] For  $V$  in Fig. 54 the rotation also round  $A$  is

$$0 = -V \cdot 37,5 + 6000 \times 12,5 = 6000 \times 25;$$

$$V = +6000 \text{ lbs.}$$

For the other members in Fig. 52,

$$0 = x_1 \cdot 13,9 + 21000 \times 37,5 - 6000 \times 12,5 - 6000 \times 25 \text{ (rot. } r. F);$$

$$x_1 = -40400;$$

$$0 = y_1 \cdot 23,5 + 6000 \times 12,5 + 6000 \times 25 \text{ (rot. } r. A);$$

$$y_1 = -9570;$$

$$0 = -z_1 \cdot 10 + 21000 \times 25 - 6000 \times 12,5 \text{ (rot. } r. G);$$

$$z_1 = +45000;$$

$$0 = -V_1 \cdot 25 + 6000 \times 12,5 \text{ (rot. } r. A);$$

$$V_1 = +3000;$$

$$0 = x_2 \cdot 9,3 + 21000 \times 25 - 6000 \times 12,5 \text{ (rot. } r. H);$$

$$x_2 = -48400;$$

$$0 = y_2 \cdot 9,3 + 6000 \times 12,5 \text{ (rot. } r. A);$$

$$y_2 = -8100;$$

$$0 = -z_2 \cdot 5 + 21000 \times 12,5 \text{ (rot. } r. I);$$

$$z_2 = +52500.$$

For the strain in  $z$ , we choose a convenient point for rotation in the line  $z$ , per Example D, Fig. 55.

55.] The equation in this case will be

$$0 = x_3 \cdot 18,6 + 21000 \times 50;$$

$$x_3 = -56500.$$

The only strain not directly deducible is  $U$  in the vertical line  $CD$  at the centre.

As in Fig. 36, we use the strain of the joining brace,

$$x = -32300 \text{ lbs.}$$

56.] For  $B$  as the point of rotation (Fig. 56), our equation is

$$0 = -U \cdot 50 - 6000 \times 50 - (-32300) \cdot 37,2;$$

$$U = 18000 \text{ lbs.}$$

57.] The results combined in Fig. 57.

The weight and load of a roof (Fig. 58) being estimated, including wind-pressure and snow, to 50 lbs. per square foot of its horizontal plan, the distance of rafters being 12 feet, and the space between the walls 99 feet, which gives  $50 \cdot 12 \cdot 99 = 59400$  lbs. for one rafter, or, in round figures, 60000 lbs.

The calculation of the top structure can be made as in the preceding example (Fig. 36).

In the main construction are six supporting points, charged as in Fig. 58. The top structure transmits one-third of the entire load, or on each post 10000 lbs. to the apexes, *ff*.

Each wall has to bear 30000 lbs.; and after subtraction of the direct load the reactive force is 26666 lbs., or, by calculation,

$$D = \frac{6666 (11 + 22)}{99} + \frac{13333 (33 + 66)}{99} + \frac{6666 (77 + 88)}{99};$$

$$D = 26666 \text{ lbs.}$$

59.] For the strain  $x_3$  we have in Fig. 59,

$$0 = -x_3 \cdot 21 - 13333 \times 16\frac{1}{2} - 6666 (27\frac{1}{2} + 38\frac{1}{2}) + D \cdot 49\frac{1}{2}$$

(rot.  $r. h$ );

or, also,

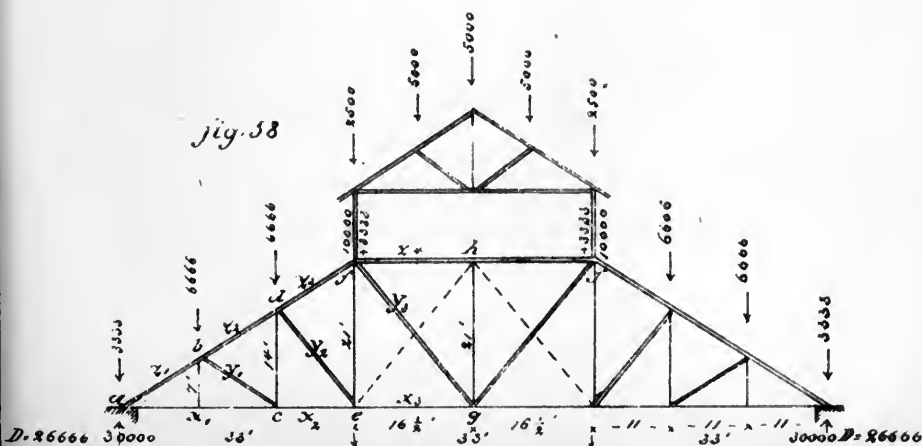
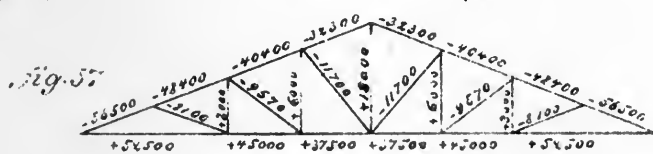
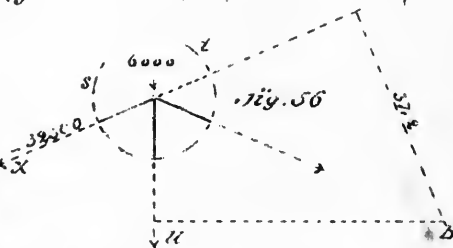
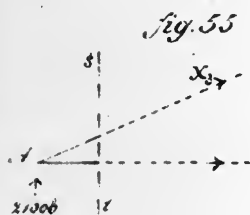
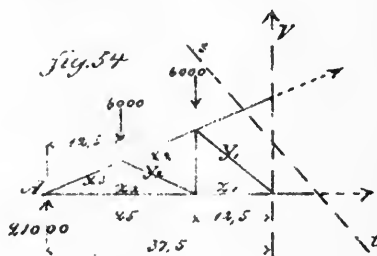
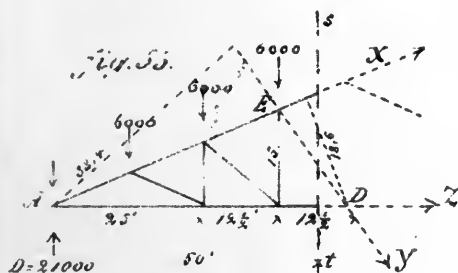
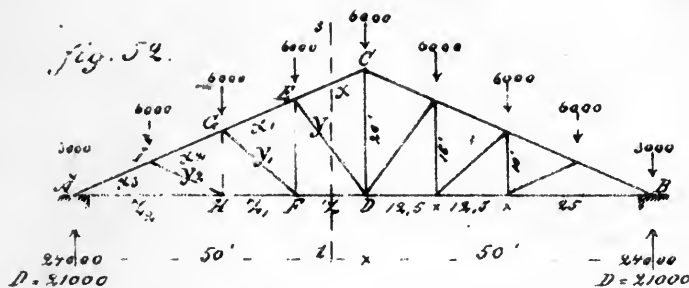
$$0 = -x_3 \cdot 21 - 6666 (11 + 22) + 26666 \times 33 \text{ (rot. } r. f);$$

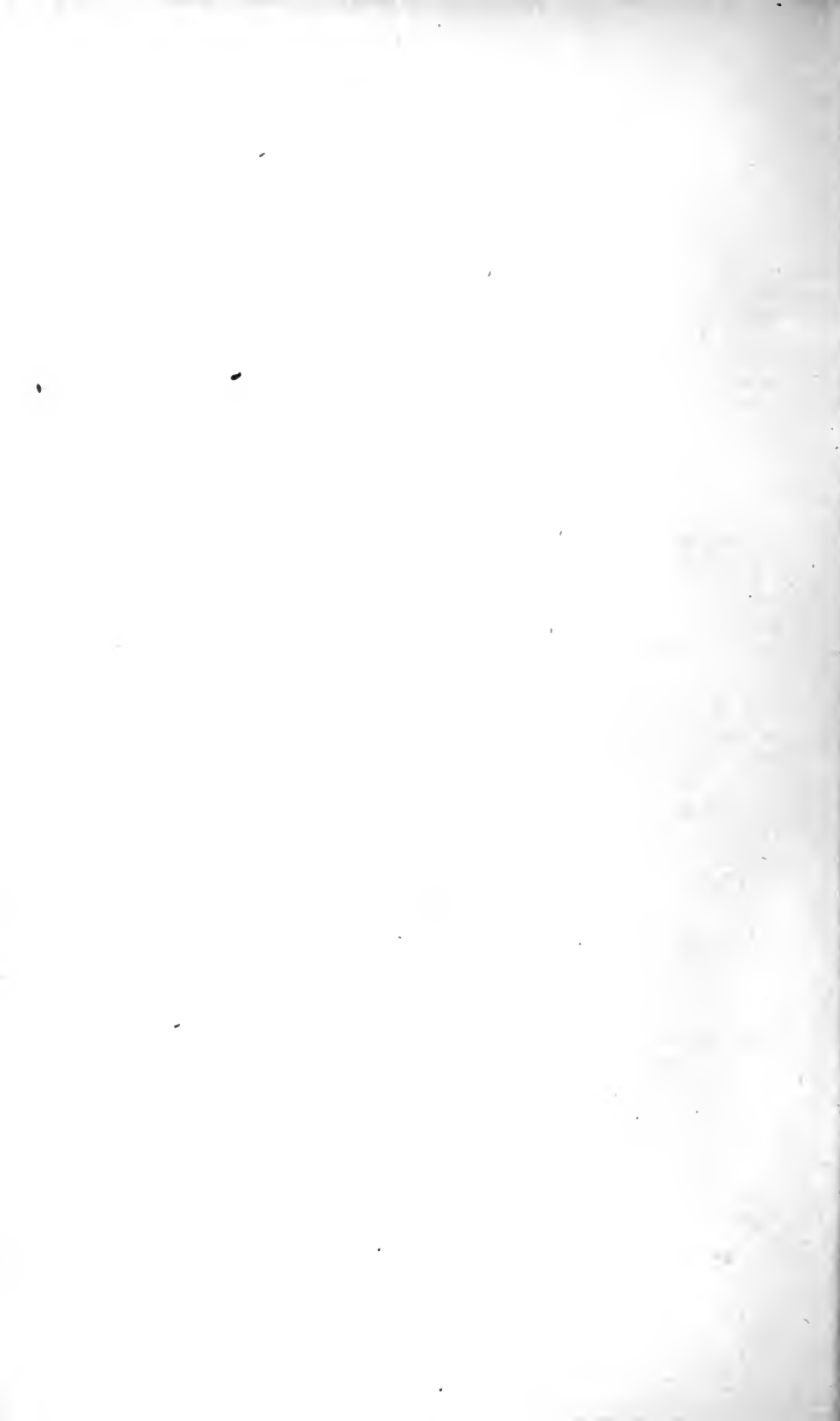
$$x_3 = + \frac{659967}{21} = +31427.$$

Further,

$$0 = Z_4 \cdot 21 - 13333 \times 16\frac{1}{2} - 6666 (27\frac{1}{2} + 38\frac{1}{2}) + D \cdot 49\frac{1}{2}$$

(rot.  $r. g$ ).





$$Z_4 = -\frac{659967}{21} = -31427,$$

$$\text{and } 0 = y_3 \cdot 39,5 + 13333 \times 33 + 6666 (11 + 22) \text{ (rot. } r. a);$$

$$Y_3 = -16708.$$

The tie-rod,  $gh$ , transmits the strain to the top flange, and is here sustained by the counter-brace,  $eh$ .

60.] From Fig. 60 is

$$0 = -x_2 \cdot 14 - 6666 \times 11 + D \cdot 22 \text{ (rot. } r. d);$$

$$x_2 = \frac{513304}{14} = 36665;$$

$$0 = z_3 \cdot 17\frac{1}{2} - 6666 (11 + 22) + 26666 \times 33 \text{ (rot. } r. e);$$

$$z_3 = -\frac{660000}{17,75} = -37180;$$

$$0 = y_2 \cdot 26,7 + 6666 \times 11 + 6666 \times 22 \text{ (rot. } r. a);$$

$$y_2 = -8223.$$

61.] Fig. 61 gives the equations,

$$0 = -x_1 \cdot 7 + 26666 \times 11 \text{ (rot. } r. b);$$

$$x_1 = +41902;$$

$$0 = z_2 \cdot 13 - 6666 \times 11 + 26666 \times 22 \text{ (rot. } r. c);$$

$$z_2 = -39485;$$

$$0 = y_1 \cdot 13 + 6666 \times 11 \text{ (rot. } r. a);$$

$$y_1 = -5640;$$

and for  $z_1$  we find from the same figure,

$$0 = z_1 \cdot 13 + 26666 \times 22;$$

$$z_1 = -45125.$$

62.] For the strain in tie-rods we find from Fig. 62.

$$0 = -V_3 \cdot 33 + 6666 \cdot (11 + 22) \text{ (rot. } r. a);$$

$$V_3 = +6666; \quad (\text{Comp. Fig. 68.})$$

$$0 = -V_2 \cdot 22 + 6666 \times 11 \text{ (rot. } r. a);$$

$$V_2 = +3333;$$

$$0 = -V_1 \cdot 11 + 0 \text{ (rot. } r. a);$$

$$V_1 = 0 \text{ (and is therefore not essential).}$$

63.] The strain in  $V_4$  at the centre rod, according to 8<sup>b</sup>, can be defined thus:

$$V_4 = 2 \times \frac{21}{26,7} \times 16708 = 26200 \text{ lbs.}$$

The results are combined in Fig. 63.

When in Fig. 64 the rafters are trussed—*i. e.*, stiffened by a king-post at *b*—there will be only four supporting points in the main construction, because the load in this case is transferred to the wall.

$$D = \frac{9999 \times 22}{99} + \frac{13333 (33 + 66)}{99} + \frac{9999 \times 77}{99} = 23332 \text{ lbs.}$$

Plate 12,]  
Fig. 65.] Further in Fig. 65,

$$0 = x_2 \cdot 21 - 13333 \times 16\frac{1}{2} - 9999 \times 27\frac{1}{2} + 23332 \times 49\frac{1}{2}$$

(rot. *r. h*);

$$x_2 = 31427;$$

$$0 = z_3 \cdot 21 - 13333 \times 16\frac{1}{2} - 9999 \times 27\frac{1}{2} + 23332 \times 49\frac{1}{2}$$

(rot. *r. g*);

$$z_3 = -31427;$$

$$0 = y_2 \cdot 39,5 + 9999 \times 22 + 13333 \times 33 \text{ (rot. } r. a);$$

$$y_2 = -16708.$$

66.] And from Fig. 66,

$$0 = -x_1 \cdot 14 + D \cdot 22 = -x_1 \cdot 14 + 23332 \times 22 \text{ (rot. } r. d);$$

$$x_1 = +36665;$$

$$0 = z_2 \cdot 17\frac{3}{4} + 23332 \times 33 - 9999 \times 11 \text{ (rot. } r. e);$$

$$z_2 = -37180;$$

$$0 = y_1 \cdot 26,75 + 9999 \times 22 \text{ (rot. } r. a);$$

$$y_1 = -8223.$$

67.] For *Z* we have from Fig. 67,

$$0 = Z_1 \cdot 13 + 23332 \times 22 \text{ (rot. } r. c);$$

$$Z_1 = -39485.$$

68.] See the results in Fig. 68 combined.

The strain  $V_4 = 26200$  lbs. can be defined independently of the Method of Moments by the parallelogram of forces, as in Fig. 63, already shown,

$$V_4 = 2 (-16708) \cdot \cos \alpha;$$



*fig. 60.*



Fig. 62

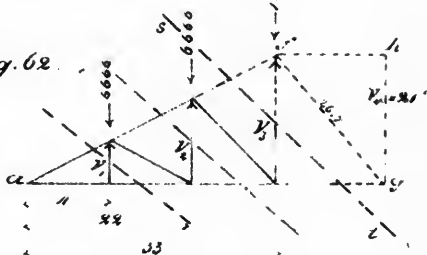


Fig. 63

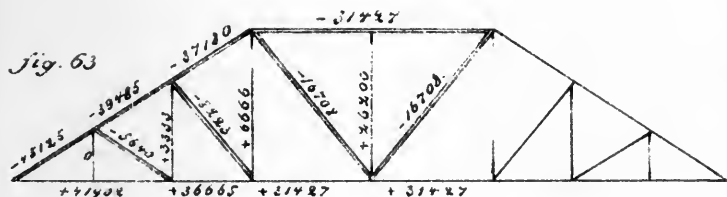
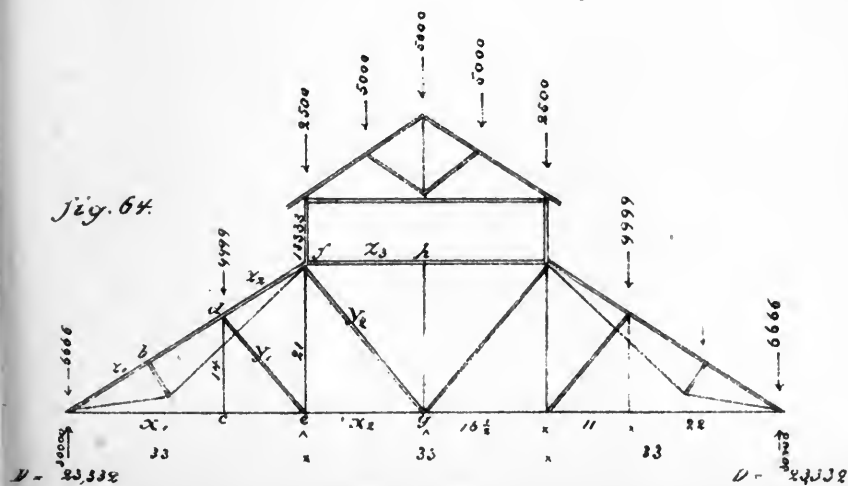
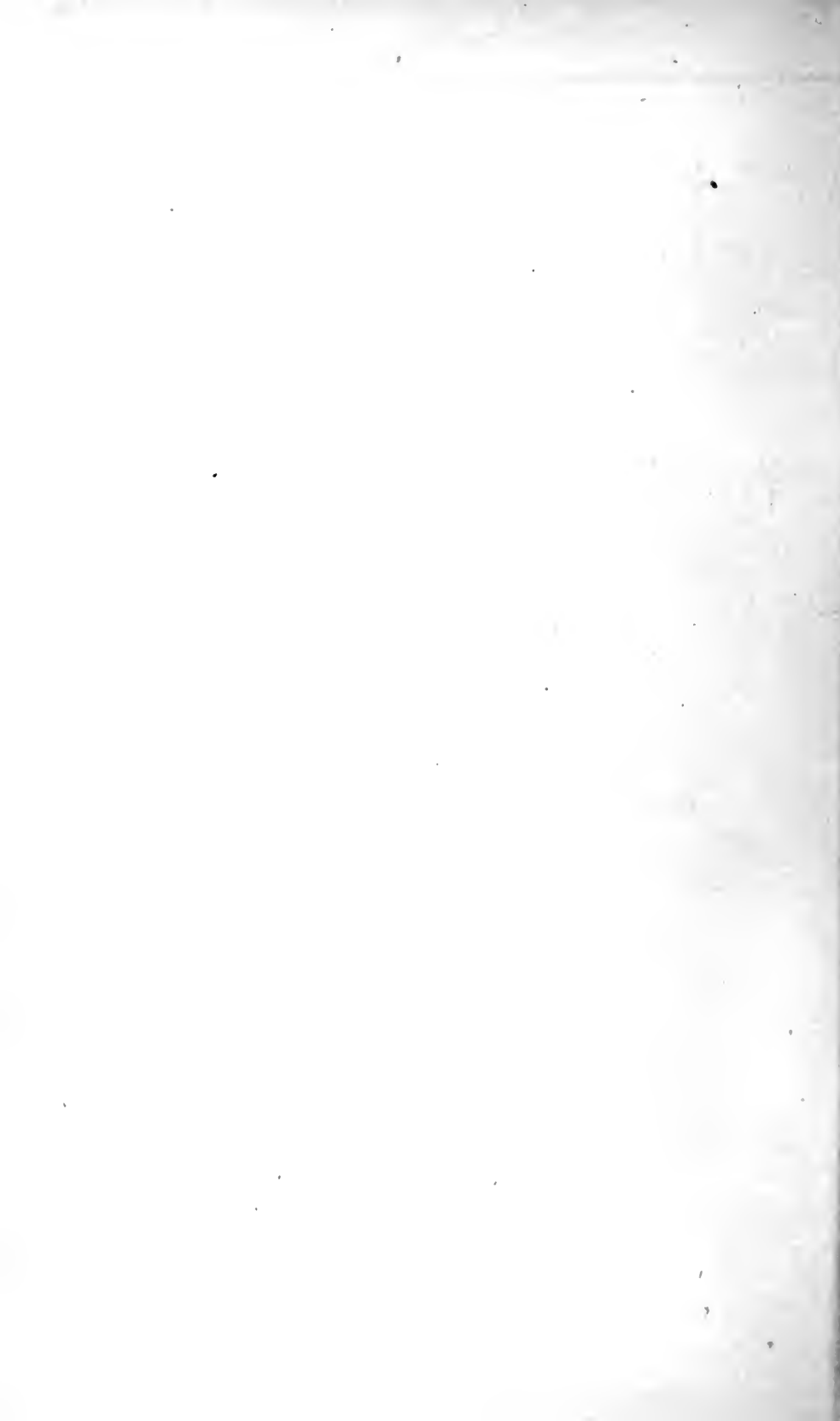
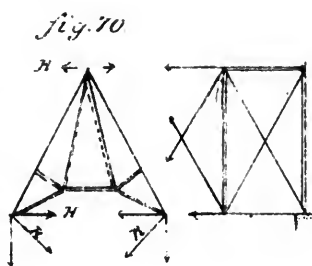
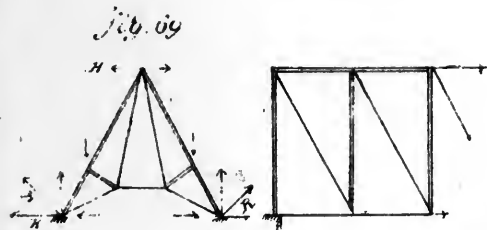
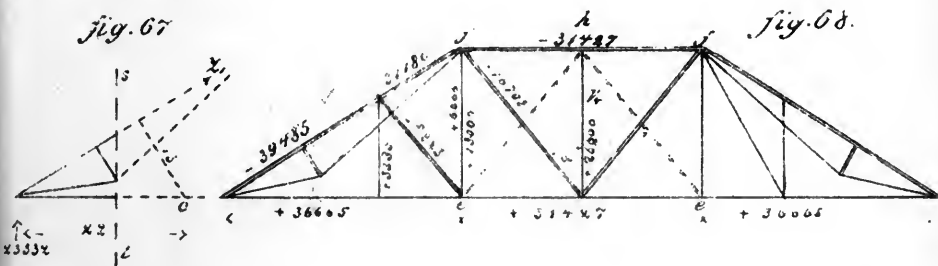
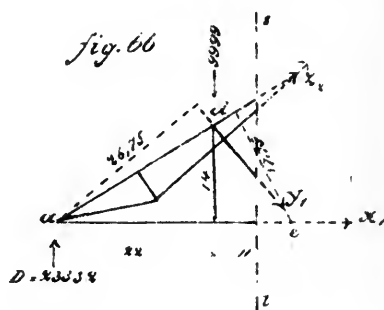
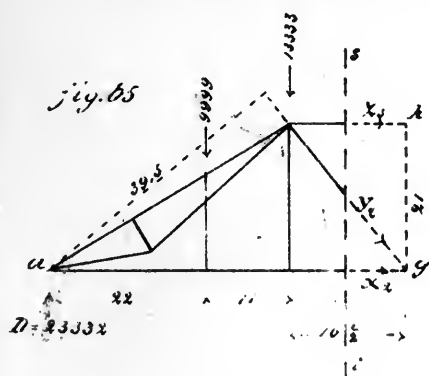
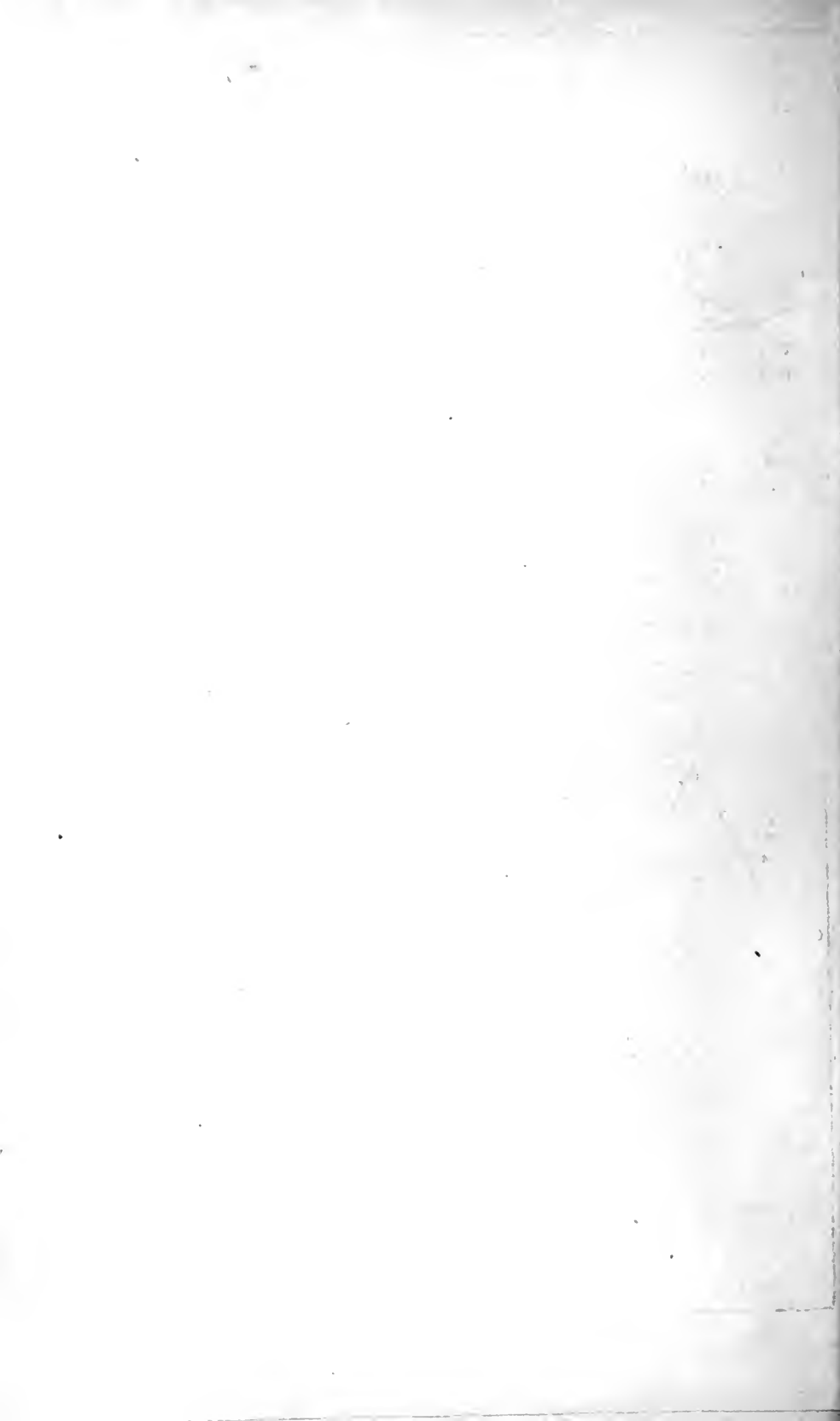


Fig. 64.









and when by means of counter-braces,  $e, h$ , the top chord is relieved from the strain, so that one-half to each side is transported to the tie-rods,  $e, f$ , then here the strain will increase to  $13000 + 6666 = 19666$  lbs.

69,] In a combination of rafters (Figs. 69, 70), the pressure of  
70.] the end rafters upon the wall results in an outward horizontal and vertical force.

Different from this is the action of the intermediate rafters, being similar to an oblique bridge-truss, sustained at the top chord.

The horizontal force at the heels of the intermediate rafters is opposed to the horizontal force of the end rafters.

[Plates 6, 7, 8, 9, 10, 11 and 12—embracing Figs. 31 to 70.]

## C. SEMI-GIRDERS.

### I. SEMI-GIRDERS LOADED AT THE EXTREMITY.

Plate 13,] As the most simple presentation for a weight,  $W$ , the  
Fig. 71.] stress in struts and tie-rods is inscribed in Figs. 71 to 74, and the parallelogram of forces connected.

73.] To compute in Fig. 73 the stress in the lower flange, we have

$$\frac{de}{df} = \sec \alpha, \quad \text{and} \quad \frac{\frac{Z}{2}}{-W \cdot \sec \alpha} = -\sin \alpha,$$

or 
$$\frac{Z}{2} = -W \cdot \sec \alpha \cdot \sin \alpha;$$

$$Z = -W \cdot \sec \alpha \cdot \sin \alpha - W \cdot \sec \alpha \sin \alpha,$$

or 
$$Z = -2W \cdot \sec \alpha \cdot \sin \alpha;$$

and since 
$$\sin \alpha = \frac{\tan \alpha}{\sec \alpha},$$

$$Z = -2W \cdot \sec \alpha \frac{\tan \alpha}{\sec \alpha} = -2W \cdot \tan \alpha$$

(much easier determined in Fig. 77 by the Method of Moments).

From Fig. 73 and the following we see that, for a load at the extremity, the diagonals are strained equally and alternately with tensile (+) and compressive (−) strains. (Comp. Fig. 23.)

But the strain in the flanges increases toward the support in each,

$$2 W. \tan \alpha ,$$

where  $\alpha$  is the angle of diagonals with a vertical line.

75.] For a better presentation of this, see Fig. 75, and for the calculation apply the Method of Moments.

76, 77.] When by a cut, *st*, a section of the structure is separated, we have for the flanges as equation of equilibrium (Figs. 76 and 77),

$$0 = -x_1 \cdot cb + W \cdot ca \text{ (rot. } r. b \text{)}; \quad 0 = +z_1 \cdot h + W \cdot 2l \text{ (rot. } r. d \text{)};$$

or for  $cb = h$ , and  $ac = l$ ;

$$x_1 = +W \cdot \frac{l}{h} = +W \cdot \tan \alpha; \quad z_1 = -2W \cdot \frac{l}{h} = -2W \cdot \tan \alpha;$$

78] and by Figs. 76 and 79:

$$0 = -x_2 \cdot h + W \cdot 3l \text{ (rot. } r. e \text{)}; \quad 0 = +z_2 \cdot h + W \cdot 4l \text{ (rot. } r. f \text{)};$$

$$x_2 = +3W \cdot \frac{l}{h} = 3W \cdot \tan \alpha. \quad z_2 = -4W \cdot \frac{l}{h} = -4W \cdot \tan \alpha.$$

In the same manner is

$$0 = -x_3 \cdot h + W \cdot 5l \text{ (rot. } r. g \text{)}; \quad 0 = +z_3 \cdot h + W \cdot 6l \text{ (rot. } r. h \text{)};$$

$$x_3 = 5W \cdot \frac{l}{h} \quad z_3 = -6W \cdot \frac{l}{h}.$$

### CRANES.

Plate 14, Fig. A.] A wrought-iron crane (Fig. A), constructed of braces with link-joints, may be loaded at the extremity with 30000 lbs. =  $P$ ; so is (for the dimensions noted in the skeleton) the horizontal strain,  $S$ , in  $a$  and  $b$ .

$$0 = -S \cdot 6 + P \cdot 12 \text{ (rot. } r. a \text{)};$$

$$S = 60000 \text{ lbs};$$

B.] and for the other members we have

$$0 = -z_1 \cdot 0,75 + 0 \text{ (rot. in the intersection of } y_1 \text{ and } x_1 \text{ or } g, \text{ Fig. B)};$$

$$z_1 = 0;$$

$$0 = y_1 \cdot 1,1 - P \cdot 2,1 \text{ (rot. } r. i \text{)};$$

$$y_1 = + \frac{30000 \times 2,1}{1,1} = 57272;$$

fig. 71.

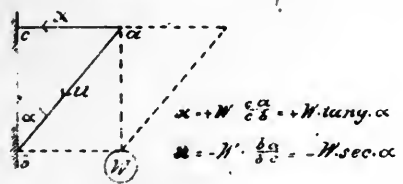


fig. 72

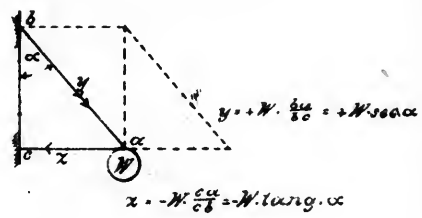


fig. 73

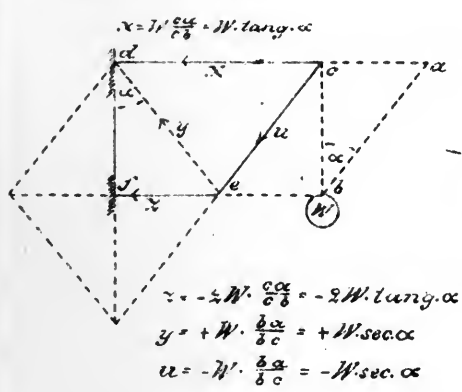


fig. 74

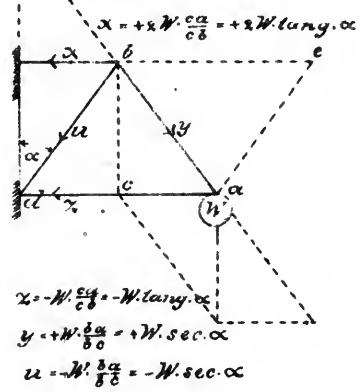


fig. 75

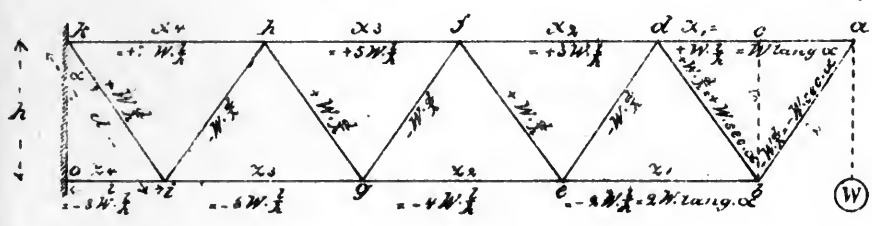


fig. 76

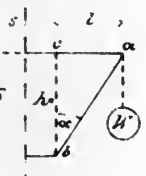


fig. 77

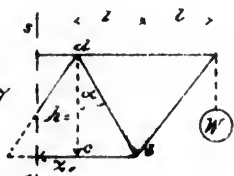


fig. 78

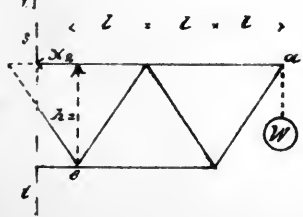
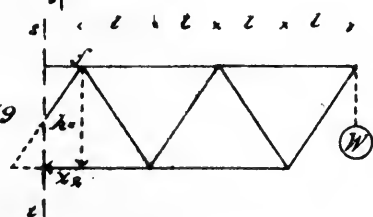
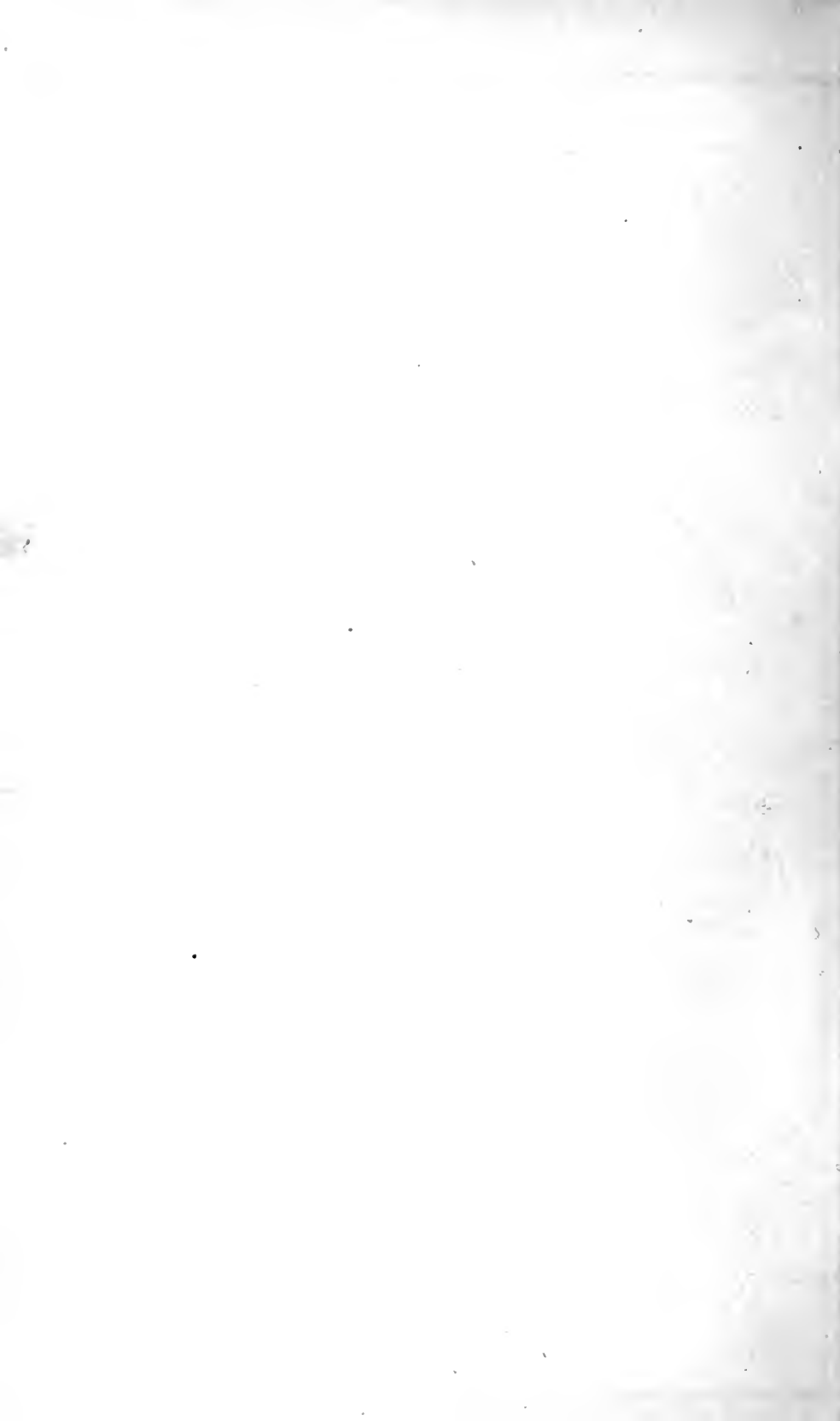
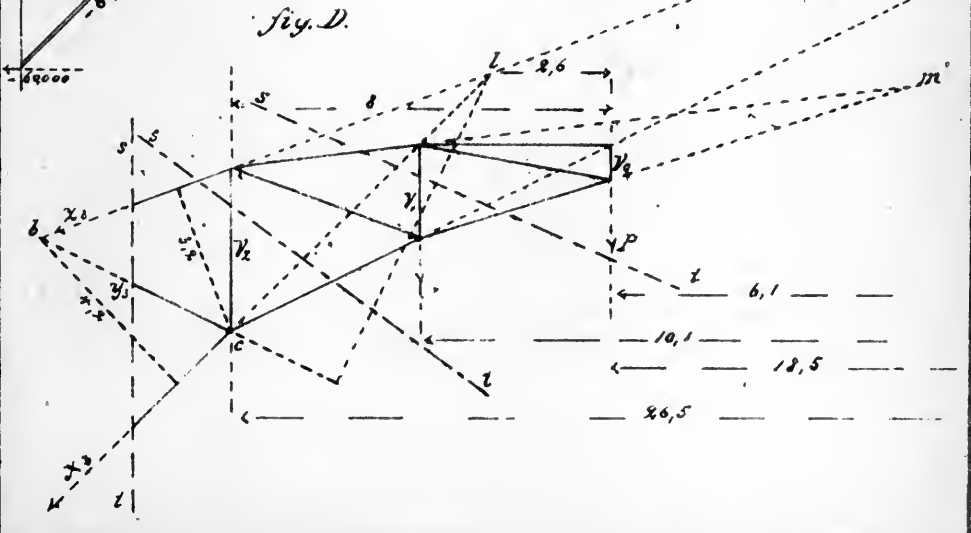
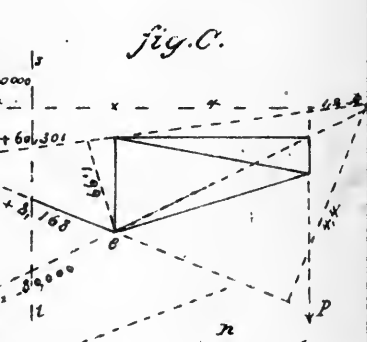
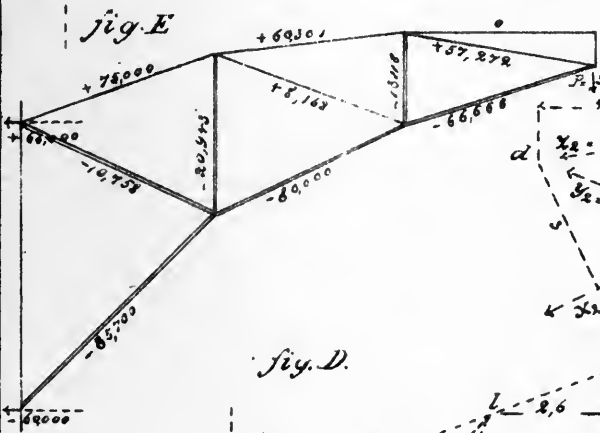
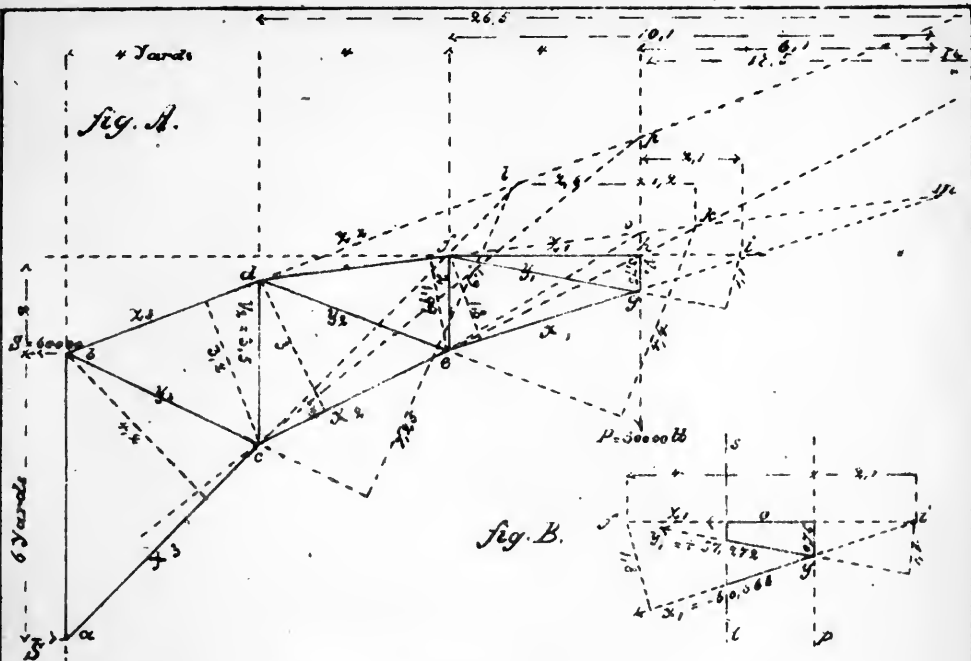


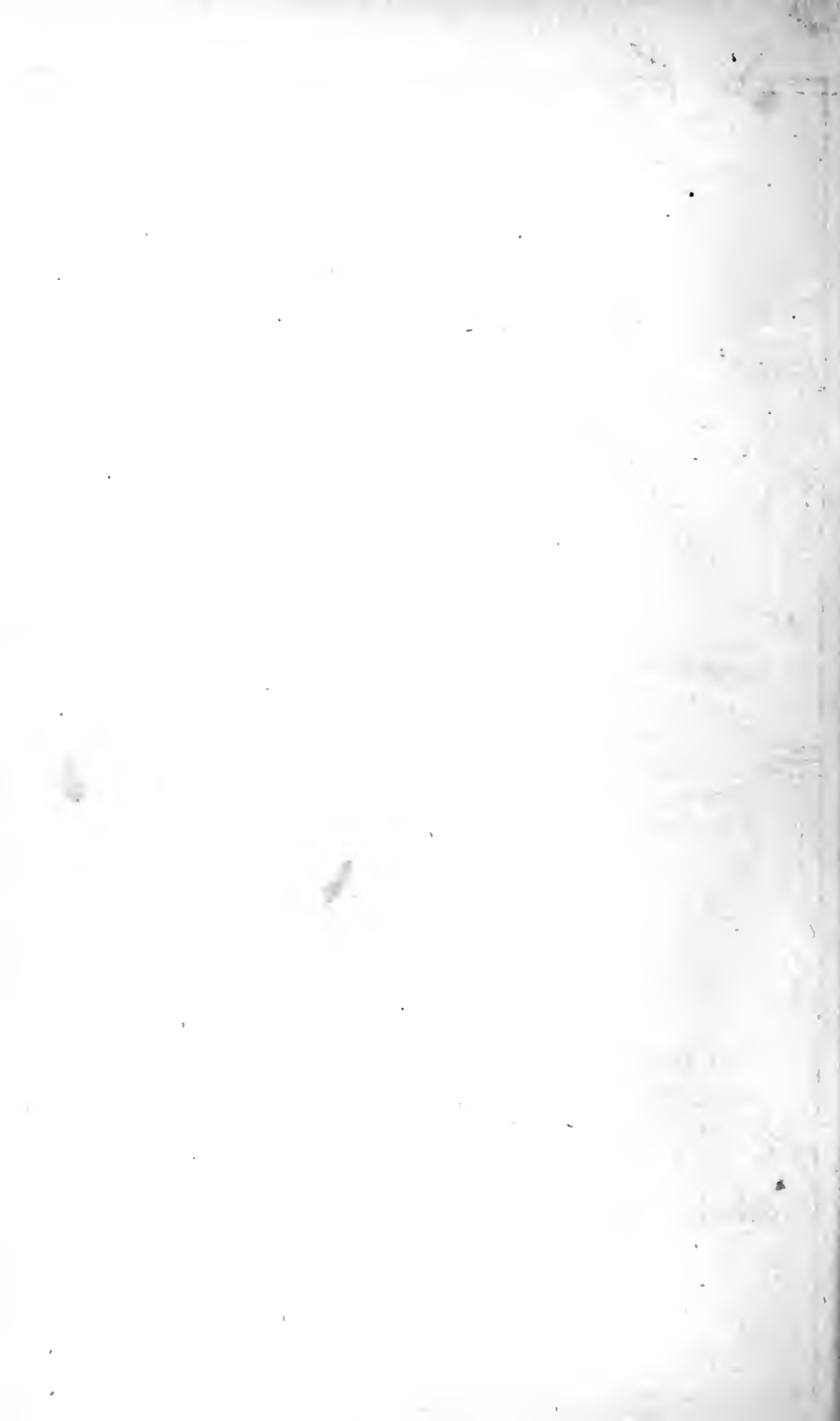
fig. 79











$$0 = x_1 \cdot 1,8 + P \cdot 4 \text{ (rot. } f \text{)};$$

$$x_1 = -\frac{30000 \cdot 4}{1,8} = -66666;$$

C.]  $0 = -z_2 \cdot 1,99 + P \cdot 4 \text{ (rot. } r. e, \text{ Fig. C)};$

$$z_2 = \frac{120000}{1,99} = +60301;$$

$$0 = y_2 \cdot 4,4 - P \cdot 1,2 \text{ (rot. } r. k \text{)};$$

$$y_2 = +8168;$$

$$0 = x_2 \cdot 3 + P \cdot 8 \text{ (rot. } r. d \text{)};$$

$$x_2 = -80000;$$

D.]  $0 = -z_3 \cdot 3,2 + P \cdot 8 \text{ (rot. } r. c, \text{ Fig. D)};$

$$z_3 = 75000;$$

$$0 = x_3 \cdot 4,2 + P \cdot 12 \text{ (rot. } r. b \text{)};$$

$$x_3 = 85700.$$

For  $y_3$  the intersection  $l$  of  $x_3$  and  $z_3$  is to the left of the suspended weight, and the symbol reversed.

$$0 = y_3 \cdot 7,25 + P \cdot 2,6 \text{ (rot. } r. l \text{)};$$

$$y_3 = -10758,$$

which would be  $= 0$  when the intersection is in the vertical line of the suspended weight, as the lines  $oe$  and  $pc$  in Fig. A indicate.

For the verticals,  $V$ , we have from Fig. D,

$$0 = -V_1 \cdot 10,1 - P \cdot 6,1 \text{ (rot. } r. m \text{)};$$

$$V_1 = 18118;$$

$$0 = -V_2 \cdot 26,5 - P \cdot 18,5 \text{ (rot. } r. n \text{)};$$

$$V_2 = -20943.$$

E.] The results combined in Fig. E.\*

## II. SEMI-GIRDERS LOADED AT EACH APEX.

In Fig. 25 is occasionally explained how to compute the stress in diagonals, as there is no intersection of joining flanges,  $x$  and  $z$ , and as in the case here considered the diagonals receive at each loaded

---

\* For most purposes the above will be sufficient. In Glynn's rudimentary treatise on the Construction of Cranes we find valuable and complete drawings.

Plate 15,] apex an increment of strain, prior to the calculation  
Fig. 80.] may be given the general thesis that *the strain in two diagonals whose intersection is at an unloaded point is the same in numerical value, but of opposite character.* (Fig. 80.)

(See IV. General Remarks.)

The strain in diagonals, meeting at a loaded point, is in numerical value different.

The strain in flanges increases from apex to apex in geometrical progression.

81.] In Fig. 81 suppose the angle  $\varphi$  of diagonals with a horizontal line  $= 45^\circ$ , so, also, angle  $\alpha = 45^\circ$ ; and by the table,  $\sec \alpha = 1.414$ .

When, again, in the axis  $x = \infty$  a point of rotation,  $o$ , is supposed, we have per example for diagonal,  $y_3$ .

$$0 = + y_3 \cdot x \sin \varphi + \left( W + W + \frac{W}{2} \right) \cdot x (\text{rot. } r. o),$$

where  $y_3 \cdot \sin \varphi$  is the vertical component of  $y_3$ , or  $= ab = a_1 b_1$  in the parallelogram of forces (Fig. 81), presenting by  $y_3$  the resulting strain or diagonal. Divided by  $x$ , it follows:

$$0 = + y_3 \sin \varphi + \left( W + W + \frac{W}{2} \right);$$

and as  $\varphi = 45^\circ$ , and  $\sin 45^\circ = 0.707$ ,

$$0 = + y_3 \cdot 0.707 + \frac{5}{2} \cdot W,$$

or  $y_3 = - 3.535 W$ .

The same results from  $-\frac{5}{2} W \cdot \sec \alpha$ , or  $-\frac{5}{2} \cdot W \cdot 1.414$ , which is also  $= - 3.535 W$ .

82.] In the same manner in Fig. 82 for  $y_2$ , the direction of which, when separated by a cut, *st*, is reversed to the weight. (See Figs. 22 and 23.)

$$0 = - y_2 \cdot \sin 45 + \frac{W}{2} (\text{rot. } o);$$

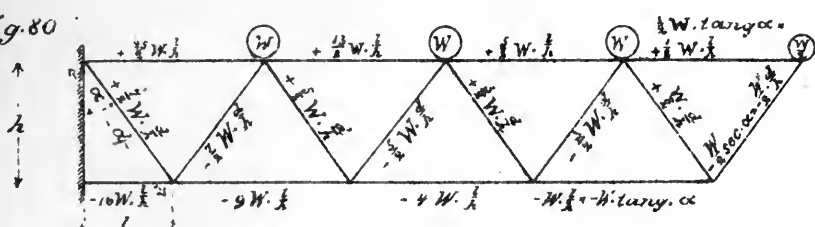
$$y_2 = + \frac{\frac{1}{2} W}{0.707}, \quad \text{and } y_1 = - \frac{\frac{1}{2} W}{0.707};$$

and for the other diagonals,

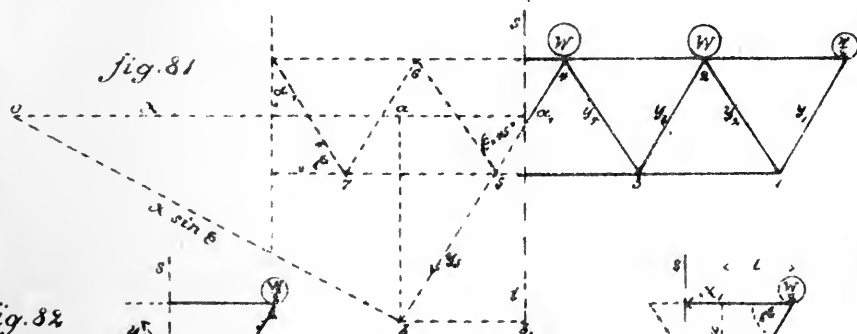
$$0 = + y_3 \cdot 0.707 + W + \frac{W}{2},$$

or  $y_3 = - \frac{\frac{3}{2} W}{0.707}, \quad \text{and } y_4 = + \frac{\frac{3}{2} W}{0.707};$

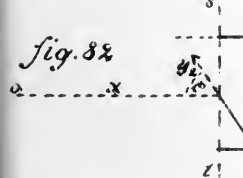
fig. 80



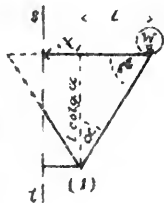
*fig. 81*



*fig. 82*



*fig. 83*



right

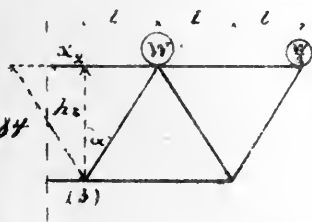


fig. 85

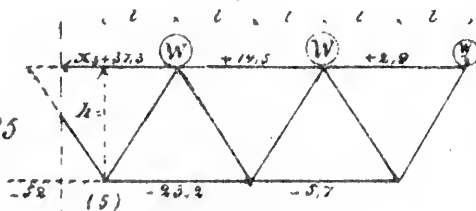


fig 86

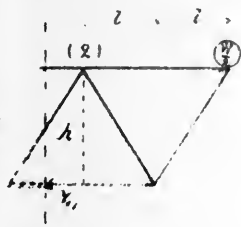


fig. 87

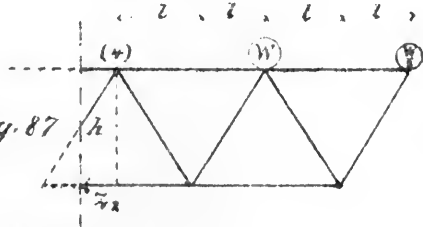
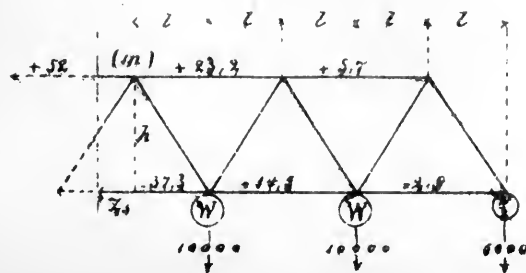


fig. 88





$$y_5 = -\frac{\frac{5}{2}W}{0,707}, \quad \text{and } y_6 = +\frac{\frac{5}{2}W}{0,707};$$

$$0 = +y_7 \cdot 0,707 + W + W + W + \frac{W}{2},$$

$$\text{or } y_7 = -\frac{\frac{7}{2}W}{0,707}, \quad \text{and } y_8 = +\frac{\frac{7}{2}W}{0,707}.$$

83.] For the strain in flanges we have from Fig. 83,

$$0 = -x_1 \cdot l \cdot \cotg \alpha + \frac{W}{2} \cdot l \text{ (rot. } r. 1);$$

$$x_1 = \frac{\frac{1}{2}W \cdot l}{l \cdot \cotg \alpha}, \quad \text{or as } \frac{1}{\cotg \alpha} = \text{tang } \alpha,$$

$$x_1 = \frac{1}{2}W \cdot \text{tang } \alpha;$$

and when  $W = 10$  tons,  $\angle \varphi = 60^\circ$ ; therefore  $\angle \alpha = 30^\circ$ ,

and  $\text{tang } 30^\circ = 0,577$  ("Example Stoney");

$$x_1 = 5 \times 0,577 = +2,9 \text{ tons};$$

or when, for an easier understanding, in Fig. 83,

$$l \cdot \cotg \alpha = h,$$

84.] we have for  $x_2$  in Fig. 84,

$$0 = -x_2 \cdot h + W \cdot l + \frac{W}{2} \cdot 3l \text{ (rot. } r. 3);$$

$$x_2 = \frac{\frac{5}{2}W \cdot l}{h};$$

$$\text{and as } \frac{l}{h} = \text{tang } \alpha = 0,577,$$

for our example,

$$x_2 = \frac{5}{2} \cdot W \cdot 0,577 = \frac{5}{2} \times 10 \times 0,577 = 14,5 \text{ tons.}$$

85.] So for  $x_3$  in Fig. 85,

$$0 = -x_3 \cdot h + W \cdot l + W \cdot 3l + \frac{W}{2} \cdot 5l \text{ (rot. } r. 5);$$

$$x_3 = \frac{13}{2} \cdot W \cdot 0,577 = 37,3 \text{ tons,}$$

and so further.

86.] For the strain,  $z$ , in the lower flanges,

$$0 = +z_1 \cdot h + \frac{W}{2} \cdot 2l \text{ (rot. } r. 2 \text{ in Fig. 86);}$$

$$z_1 = -W \cdot \frac{l}{h} = -10 \times 0,577 = -5,7 \text{ tons.}$$

87.] Fig. 87 gives

$$0 = + z_2 \cdot h + W \cdot 2l + \frac{W}{2} \cdot 4l \text{ (rot. } r. 4);$$

$$z_2 = -4W \cdot \frac{l}{h} = -4 \times 10 \times 0,577 = -23,2 \text{ tons.}$$

In the same way for  $z_3$ ,

$$0 = + z_3 \cdot h + W \cdot 2l + W \cdot 4l + \frac{W}{2} \cdot 6l;$$

$$z_3 = -9W \cdot \frac{l}{h} = -52 \text{ tons.}$$

88.] In case the load should be connected to the lower apexes (Fig. 88), the equation of equilibrium, per example for  $z_3$ , would be

$$0 = + z_3 \cdot h + W \cdot l + W \cdot 3l + \frac{W}{2} \cdot 5l \text{ (rot. } r. m);$$

$$z_3 = -\frac{13}{2} \cdot W \cdot \frac{l}{h} = -37,3 \text{ tons;}$$

i. e., the strain is the same as in the flange of the reversed figure, but of opposite character. So also is the strain the same for the other flanges. (See Fig. 88.)

*Remark.*—In the given example the strains are determined without a certain length for  $h$  or  $l$ . This is easily explained by the relation which the angle  $\varphi$  or  $\alpha$  bears to  $h$  and  $l$ , as by the extension of one, the other will increase in the same ratio.

[Plates 13, 14 and 15—embracing Figs. 71 to 88.]

## D. GIRDERS WITH PARALLEL TOP AND BOTTOM FLANGES.

(Calculated for a Permanent Load.)

### I. STRAIN IN DIAGONALS AND VERTICALS.

The calculation is very similar to the preceding. Provided, again, the load to be connected to the upper or lower apexes for the application of the Method of Moments, we now consider as a special force the reaction of the supports toward the system.

$D_1$  may represent one-half the weight of loaded truss or the



pressure upon each support (prop), and diminished by the partition of load on this place directly sustained. (Comp. Fig. 21.) The reactive force of support wanted for our calculation will be signified by  $D$ .

To compute  $D$ , we refer to Fig. 4 in Sect. I., and define first for the following example its numerical value:

Plate 16,] Through bridge (over-grade bridge), between supports,  
Fig. 89.] 48 feet;

8 panels, each 6 feet =  $l$ ;

depth of truss = 6 feet =  $h$ , from centre to centre of top and bottom chords;

the weight of structure = 3000 lbs., and the load = 15000 lbs.;

gives a permanent load = 18000 lbs. per panel;

rolling load = 0. (See Sect. II.)

For the distribution of load, see Fig. 89.

*Remark.*—The strange impression which the arrangement of diagonals, unsymmetrical toward the centre, may first produce, will soon disappear after observation of the advantages for transformation upon succeeding systems.

Whole pressure of truss upon supports =  $8 \times 18000 = 144000$  lbs.;

$D_1 = 18000 \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \frac{7}{8} \right) + 9000 \times \frac{8}{8} = 72000$  lbs.;

$D = 18000 \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \frac{7}{8} \right) = 63000$  lbs.

The strain in the post,  $V_0$ , is 0, because  $x_1 = 0$ ,

and  $V_8 = -63000$ .\*

90.] Excepting the vertical component of  $y_1$  (*i. e.*,  $y_1 \sin \varphi$ ), for a section (Fig. 90), only  $D = 63000$  lbs. is a second vertical force.

Both turn to the left around  $o$  in the axis  $x_0$ ; therefore their symbol, —. (Comp. Fig. 22.)

\* For a deck-bridge (under-grade bridge)—*i. e.*, when the upper apexes are loaded—would be

$$V_0 = -9000, \quad \text{and} \quad V_8 = -72000.$$

The angle of diagonals with a horizontal line will be  $45^\circ$ .

$$0 = -y_1 \sin 45^\circ - D \text{ (rot. } r.o.);$$

and as  $\sin 45^\circ = 0,7$ ,

$$0 = -y_1 \cdot 0,7 - 63000,$$

or

$$y_1 = -90000.$$

91.] For  $V_1$  in Fig. 91, only  $D$  is acting vertically upon this section.

$D$  turns to the left around  $o$ , therefore

$$0 = +V_1 - D \text{ (rot. } r.o.);$$

$$0 = V_1 - 63000,$$

or

$$V_1 = +63000.$$

92.] According to the preceding, from Fig. 92,

$$0 = -y_2 \cdot 0,7 + 18000 - 63000 \text{ (rot. } r.o.);$$

$$y_2 = -64285;$$

93.] and from Fig. 93,

$$0 = +V_2 + 18000 - 63000 \text{ (rot. } r.o.);$$

$$V_2 = +45000.$$

94.] Fig. 94 gives the equation,

$$0 = -y_3 \cdot 0,7 + 18000 + 18000 - 63000.$$

$$y_3 = -38570;$$

95.] and from Fig. 95 we have

$$0 = +V_3 + 18000 + 18000 - 63000;$$

$$V_3 = +27000.$$

Now it will be unnecessary to farther accompany the remaining calculations with diagrams.

$$0 = -y_4 \cdot 0,7 + 18000 \times 3 - 63000;$$

$$y_4 = -12857;$$

$$0 = +V_4 + 18000 \times 3 - 63000;$$

$$V_4 = +9000;$$

$$0 = -y_5 \cdot 0,7 + 18000 \times 4 - 63000;$$

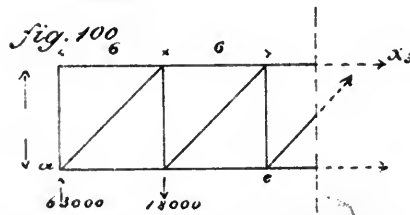
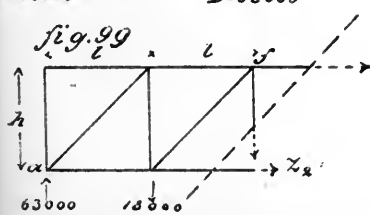
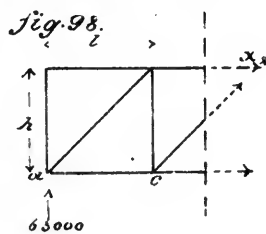
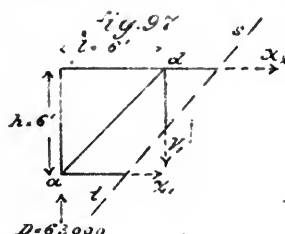
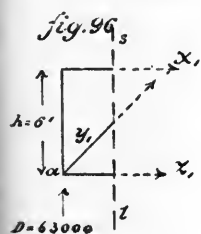
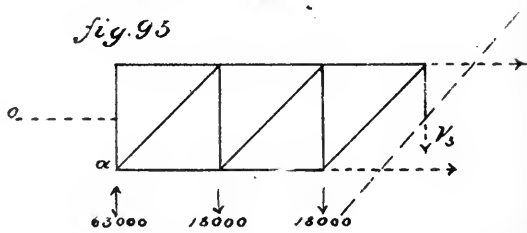
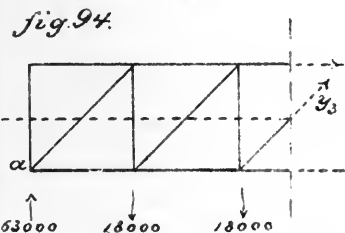
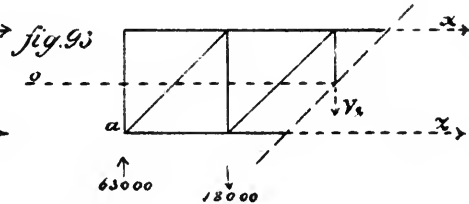
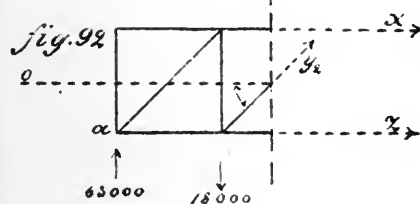
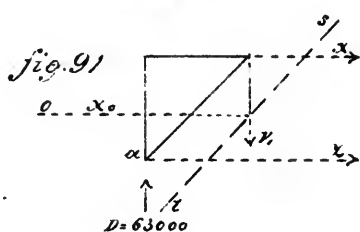
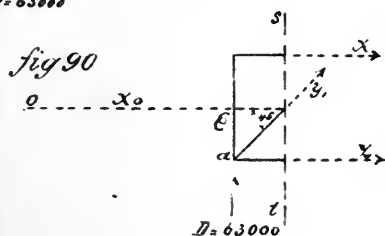
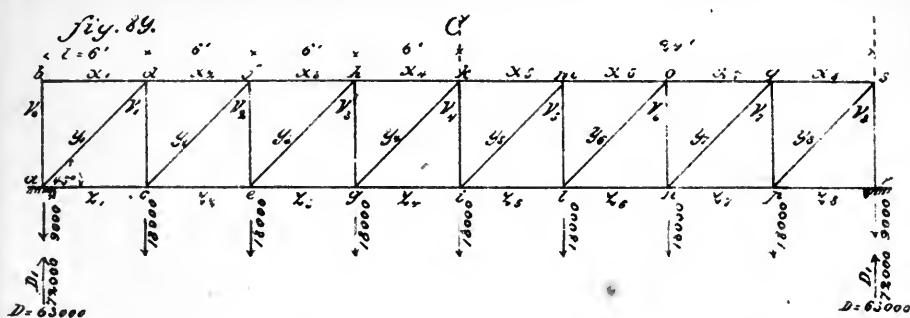
$$y_5 = +12857;$$

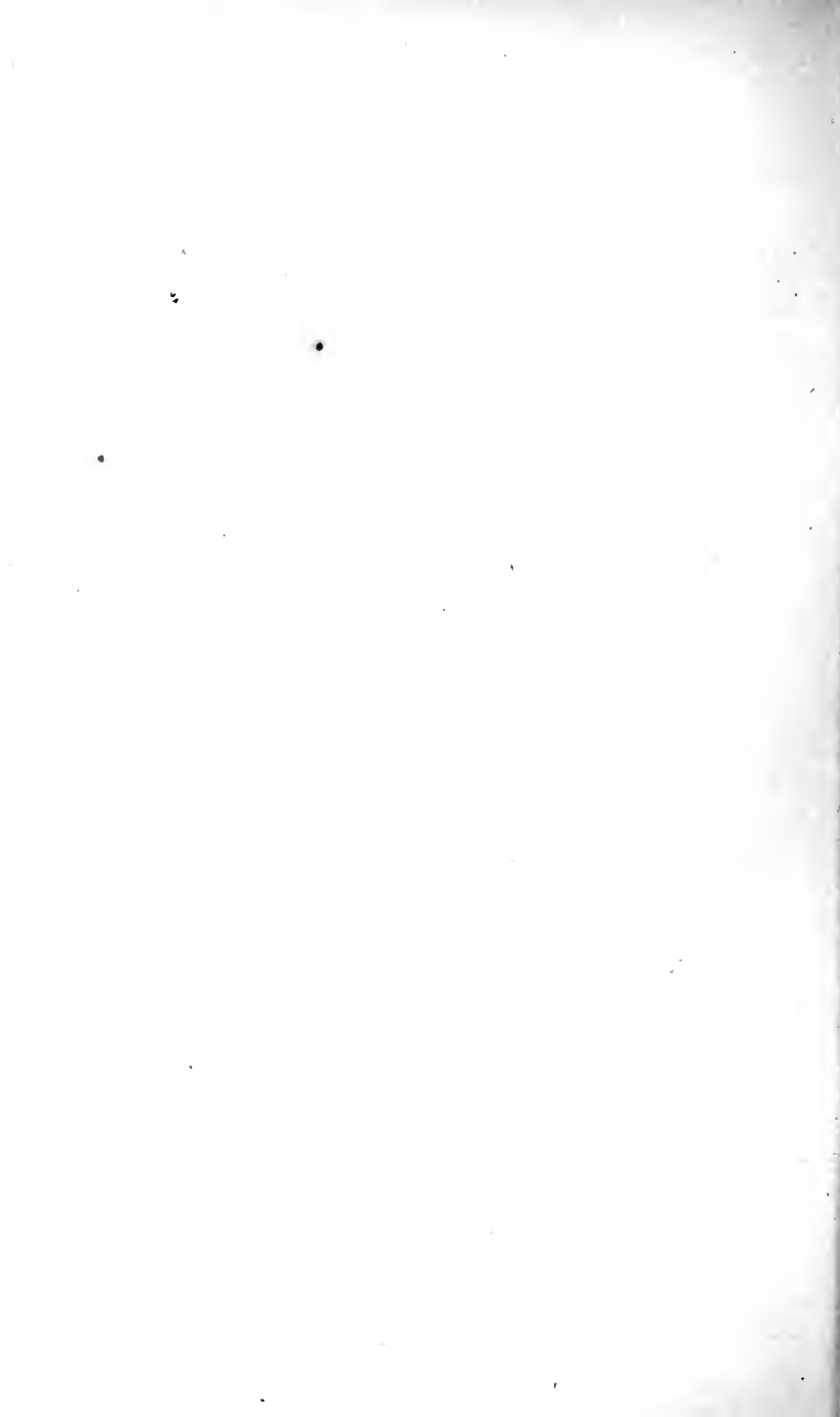
$$0 = +V_5 + 18000 \times 4 - 63000;$$

$$V_5 = -9000;$$

$$0 = -y_6 \cdot 0,7 + 18000 \times 5 - 63000;$$

$$y_6 = +38570;$$





$$0 = +V_6 + 18000 \times 5 - 63000;$$

$$V_6 = -27000;$$

$$0 = -y_7 \cdot 0.7 + 18000 \times 6 - 63000;$$

$$y_7 = +64285;$$

$$0 = +V_7 + 18000 \times 6 - 63000;$$

$$V_7 = -45000;$$

$$0 = -y_8 \cdot 0.7 + 18000 \times 7 - 63000;$$

$$y_8 = +90000;$$

$$0 = +V_8 + 18000 \times 7 - 63000;$$

$$V_8 = -63000.$$

## II. STRAIN IN FLANGES.

The calculation of strain in flanges differs in so far from the preceding, and will give no difficulty in understanding, as here a suitable point of rotation—*i.e.*, an intersection of those members, separated by a cut, *st*, similar to that one for which we want to compute the strain—is directly presented by the apexes.

For a rough and preliminary control of strain in the top and bottom flanges at the centre of the truss, it is, as  $72000 =$  one-half of the load, 6 feet = depth, and 12 feet = one-fourth of the space between the supports:

$$\frac{72000 \times 12}{6} = 144000 \text{ lbs., the horizontal strain in each flange.}$$

(Comp. Sect. I., Fig. 28.)

96.] For Fig. 96 we have the equation of equilibrium,

$$0 = x_1 \cdot h + D \cdot 0 \text{ (rot. in the intersection of } y_1 \text{ and } z_1 \text{ or } a);$$

$$x_1 = 0;$$

97.] and for Fig. 97,

$$0 = -z_1 \cdot h + D \cdot l \text{ (rot. in the intersection of } V_1 \text{ and } x_2 \text{ or } d);$$

$$z_1 = D \cdot \frac{l}{h} = 63000.$$

98.] In the same way for Fig. 98,

$$0 = x_2 \cdot h + D \cdot l \text{ (rot. } r. c);$$

$$0 = x_2 \cdot 6 + 63000 \times 6;$$

$$x_2 = -63000;$$

99.] and for Fig. 99,

$$0 = -z_2 \cdot h - 18000 \cdot l + D \cdot 2l \text{ (rot. } r.f.);$$

$$0 = -z_2 \cdot 6 - 18000 \times 6 + 63000 \times 12;$$

$$z_2 = +108000.$$

100.]  $0 = x_3 \cdot 6 - 18000 \times 6 + 63000 \times 12$  (rot.  $r.e$ , Fig. 100);

$$x_3 = -108000.$$

Plate 17,]  $0 = -z_3 \cdot 6 - 18000(6 + 12) + 63000 \times 18$  (rot.  $r.h$ ,  
Fig. 101.] Fig. 101);

$$z_3 = +135000.$$

In the same way for the other flanges,

$$0 = x_4 \cdot 6 - 18000(6 + 12) + 63000 \times 18 \text{ (rot. } r.g, \text{ Fig. 89);}$$

$$x_4 = -135000;$$

$$0 = -z_4 \cdot 6 - 18000(6 + 12 + 18) + 63000 \times 24 \text{ (rot. } r.k);$$

$$z_4 = +144000;$$

$$0 = x_5 \cdot 6 - 18000(6 + 12 + 18) + 63000 \times 24 \text{ (rot. } r.i);$$

$$x_5 = -144000;$$

$$0 = -z_6 \cdot 6 - 18000(6 + 12 + 18 + 24) + 63000 \times 30 \text{ (rot. } r.m);$$

$$z_6 = +135000;$$

$$0 = x_6 \cdot 6 - 18000 \times 60 + 63000 \times 30 \text{ (rot. } r.l);$$

$$x_6 = -135000;$$

$$0 = -z_6 \cdot 6 - 18000 \times 90 + 63000 \times 36 \text{ (rot. } r.o);$$

$$z_6 = +108000;$$

$$0 = -x_7 \cdot 6 - 18000 \times 90 + 63000 \times 36 \text{ (rot. } r.n);$$

$$x_7 = -108000;$$

$$0 = -z_7 \cdot 6 - 18000 \times 126 + 63000 \times 42 \text{ (rot. } r.q);$$

$$z_7 = +63000;$$

$$0 = -x_8 \cdot 6 - 18000 \times 126 + 63000 \times 42 \text{ (rot. } r.p);$$

$$x_8 = 63000;$$

$$0 = -z_8 \cdot 6 - 18000 \times 168 + 63000 \times 48 \text{ (rot. } r.s);$$

$$z_8 = 0.$$

102.] From the calculation of the first panel for a reversed system (Fig. 102), it will be perceived that here the results are the same as before, and so also for the other panels;

$$0 = + y_1 \cdot \sin 45^\circ - D \text{ (rot. } r. o \text{)};$$

$$0 = y_1 \cdot 0,7 - 63000;$$

$$y_1 = \frac{63000}{0,7} = + 90000;$$

$$0 = + x_1 \cdot h + D \cdot l \text{ (rot. in the intersection of } y_1 \text{ and } z_1, \text{ or } c \text{)};$$

$$0 = x_1 \cdot 6 + 63000 \times 6;$$

$$x_1 = - 63000;$$

$$0 = - z_1 \cdot h + D \cdot 0 \text{ (rot. in the intersection of } y_1 \text{ and } x_1, \text{ or } b \text{)};$$

$$z_1 = 0.$$

- 103.] The results of the foregoing are combined in Fig. 103, the compressive strains being represented by double lines.

### III. TRANSFORMATIONS.

- 104.] Truss symmetrical to the centre, with vertical tie-rods and oblique braces. (Howe's system, Fig. 104.)

- 105.] Pratt truss (Fig. 105), with oblique tie-rods and vertical braces, in which the vertical anchors, *a*, *b*, on the abutment can be spared, the same as in Fig. 114.\*

### IV. GENERAL REMARKS.

- 106.] For Howe's system (deck-bridge, Fig. 106), there will be in the vertical end post a compression = 9000 lbs., at the centre post 0, and for the reversed system at the centre post, 18000.

Further specification of this and the reversed and combined system, also for the isometrical truss, will be found in the connected tables (Figs. 108 to 117), forming thus a useful guide, especially for the strain in flanges.

*The strain in flanges being a maximum for a full load is to be calculated always for a full load, also in the case of a combined (permanent and rolling) load, and it will be treated accordingly in the following pages.*

The influence of a *rolling* load upon braces and tie-rods, being so far unconsidered, is very essential, as there is at the centre a tendency to horizontal dislocation, which is prevented in the Howe

---

\* Keystone Bridge Company, Pittsburg.

truss by counter-braces, in the isometrical truss by counter-rods, and in other bridges by panel-rods or braces.

In regard to the connecting of a load, we will only remark that for both permanent and rolling loads it is quite the same for the diagonals and horizontal flanges whether the load is connected on the top (deck-bridge) or on the bottom (through-bridge) or to the vertical posts.

But for the post itself in the last case we have to consider the thesis, that

*The vertical component of diagonals is equal to the strain in verticals—only of opposite character—when they meet at an unloaded point.*

When, therefore, the load is connected between the top and bottom of the vertical brace, both top and bottom apexes are unloaded points; hence the strain in the upper and lower part of the vertical is the vertical strain (vertical component) of the adjoining diagonal, only of opposite character.

So, for example, would be for the post  $V_7$ , in Fig. 105, in the lower part,

$$- 90000 \cdot \sin 45^\circ,$$

or 
$$- 90000 \times 0,7 = - 63000,$$

which is the vertical component of the adjoining diagonal, the symbol being reversed.

107.] In the upper part would be (Fig. 107),

$$- 64285 \times 0,7 = - 45000 \text{ lbs. (according to the same thesis).}$$

In general, we can derive the strain in the verticals from the diagonals without difficulty. So for the same post,  $V_7$ , from Fig. 105,

$$V_7 = - y_7 \cdot \cos 45 = - 64285 \times 0,7 = - 45000,$$

and 
$$V_6 = - 38570 \times 0,7 = - 27000;$$

$$V_5 = - 12857 \times 0,7 = - 9000.$$

#### DIRECTIONS FOR THE CALCULATION OF COMPLEX SYSTEMS.

For complex systems, as shown in the post bridge,\* the Linville, etc. (Fig. 107<sup>a</sup> to 107<sup>e</sup>), the calculation may be made for each system separately, to derive the strain in braces and tie-rods. For

---

\* Atlantic Bridge Works, New York.



fig. 101.

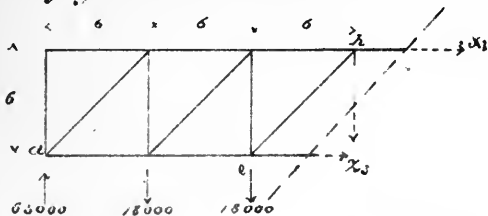


fig. 102

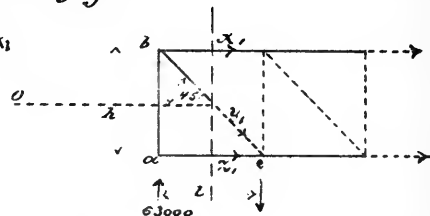


fig. 103

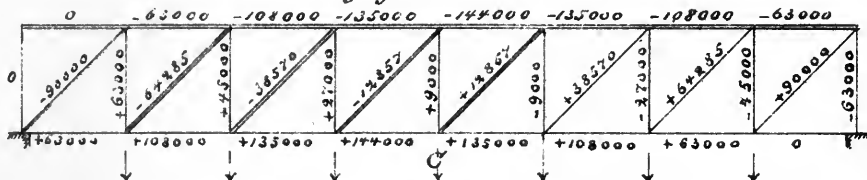


fig. 104



fig. 105

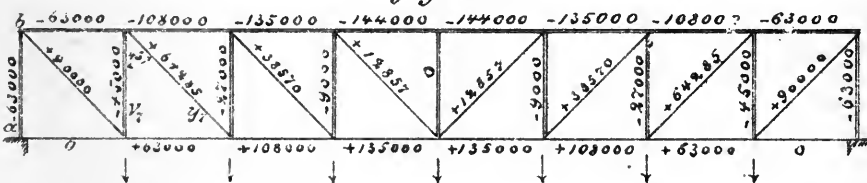


fig. 106

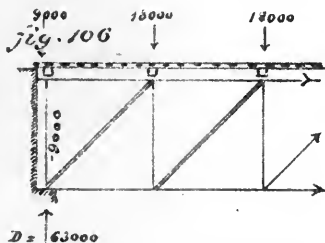
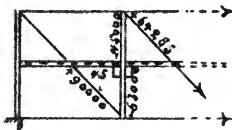
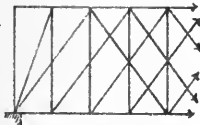
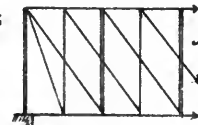
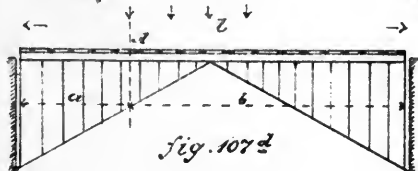
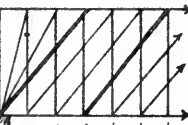
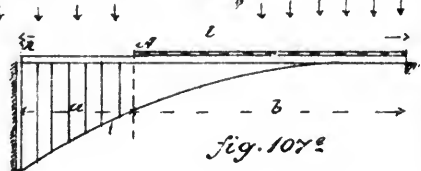
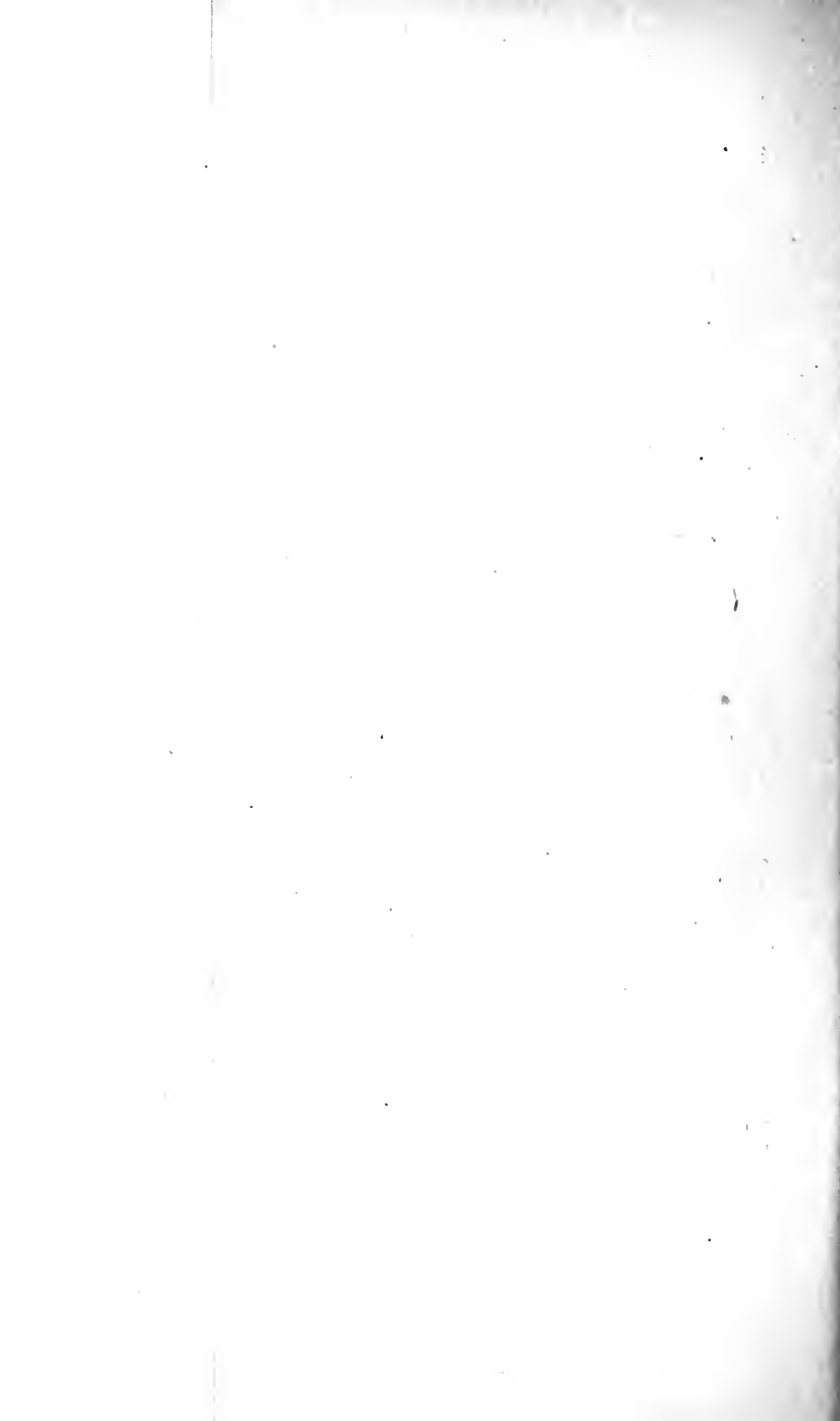


fig. 107

fig. 107<sup>a</sup>fig. 107<sup>b</sup>fig. 107<sup>c</sup>fig. 107<sup>d</sup>fig. 107<sup>e</sup>



the strain in flanges, in laying the skeletons together, the covering parts of the flanges can be added, as shown in Sect. II. on the isometrical truss, Fig. 146.\*

In the same way, by observation of the angles, this method can be applied to lattice systems.

When, in Fig. 107<sup>d</sup>,  $q$  is the weight per unit of length (foot), so, 107<sup>e</sup>.] for an equally-distributed load, is  $\frac{q \cdot l}{2}$  the shearing strain on the abutment, and at a point,  $A$ , the shearing strain =

$$q \cdot \frac{a+b}{2} - q \cdot a = \frac{q}{2} (b-a);$$

but at the centre = 0.

107<sup>a</sup>.] When the greater segment of a girder is loaded (Fig. 107<sup>e</sup>), the shearing strain at a point,  $A$ , is

$$q \cdot \frac{b^2}{2 \cdot l} = \text{the reaction, } R, \text{ of the abutment.}$$

This is the shearing strain throughout the segment  $a$ , and increases, when the load moves forward, in the same ratio as the ordinates of a parabola.

Subtracting the former quantity from the latter—i. e.,

$$\frac{q \cdot b^2}{2 \cdot l} - \frac{q}{2} \cdot (b-a) = q \cdot \frac{a^2}{2 \cdot l},$$

showing that the shearing strain is greater when, instead of the whole girder, the greater segment is loaded; and this quantity is the shearing strain throughout the segment  $b$  when the shorter segment,  $a$ , is loaded. (Mr. Stoney.)†

[Plates 16 and 17—embracing Figs. 89 to 107.]

\* Isometrical Truss Bridge Company, Pottstown, Pa.

† Mr. Shreve, in Van Nostrand's "Eclectic Engineering Magazine," No. xx., August, 1870; Vol. III., page 193.

## E. COMPARATIVE TABLES OF RESULTING STRAINS FOR A PERMANENT LOAD.

(*To Derive the Strains without Special Calculation.*)

### I. SYSTEM OF RIGHT-ANGLED TRIANGLES.

**a. Single System**—oblique braces, vertical tie-rods, Fig. 108. (Howe truss.)

1. Through Bridge (over-grade bridge).

$p$  signifies the load and weight for one-half panel; therefore  $2p$  is the vertical strain at each apex.

For a full load, denoting the number of panels in one-half of the girder with  $n$  (here = 5), and the respective panels from centre of truss toward the end with  $x$ ,

$$H_0 = +2p; \quad H_x = + (2x + 1) \cdot p; \quad H_n = 0;$$

$$D_x = - (2x - 1) p \cdot \frac{d}{h}; \quad S_x = + [n^2 - (x - 1)^2] p \cdot \frac{b}{h};$$

$$P_x = -S(x + 1) = - (n^2 - x^2) p \cdot \frac{b}{h};$$

2. Deck Bridge (under-grade bridge).

Plate 18,] Here the tension in the vertical connections (tie-rods)  
Fig. 108.] will be diminished each  $2p$ ; i. e., in the skeleton (Fig. 108),

$$H_0 = 0; \quad H = +p; \quad H_x = +3p; \quad H_5 = +5p, \text{ etc.}$$

The vertical post on the abutment will have the compression =  $-p$ .

In the strain in flanges and oblique braces there will be no difference.

**b. Single System**—vertical braces, oblique tie-rods. (Fig. 109.)

1. Through Bridge.

For a full load,

$$H_0 = 0; \quad H_x = - (2x - 1) \cdot p;$$

$$D_x = + (2x - 1) p \cdot \frac{d}{h}; \quad p_x = - [n^2 - (x - 1)^2] p \cdot \frac{b}{h};$$

$$S_x = +P(x+1) = + (n^2 - x^2) p \cdot \frac{b}{h}.$$

## 2. Deck Bridge.

109.] The strain in the vertical braces will be increased each  $-2p$ , so that in the skeleton (Fig. 109),

$$H_0 = -2p; \quad H_1 = -3p; \quad H_2 = -5p, \text{ and so on.}$$

The compression in the vertical post on the abutment will be increased by  $p$ ; therefore

$$H_5 = -10p.$$

## c. Combined System.

110<sup>a</sup>.] 1. For a full load by a through bridge (Fig. 110<sup>a</sup>), the tension in the vertical connections all the same, or

$$H_x = +p.$$

The vertical post on the abutment has the compression,

$$H_n = - (n - \frac{1}{2}) p.$$

For any one panel the tension and compression in the crossing diagonals, and also the strain in the upper or lower flange, is the same—i. e.,

$$D_x = \pm (x - \frac{1}{2}) p \cdot \frac{d}{h};$$

$$P_x = S_x = \pm \left( n^2 - \frac{x^2 + (x-1)^2}{2} \right) \cdot p \cdot \frac{b}{h}.$$

2. For a deck-bridge changes the tension  $+p$  in the vertical connections to compression, or  $-p$ .

110<sup>a</sup>.] The compression in the vertical post on the abutment will be increased by  $-p$ ; therefore in the above skeleton,

$$H_5 = -5\frac{1}{2} \cdot p.$$

3. For the system of right-angled triangles, when the connecting of cross-beams is not on the top or bottom, but between both on the verticals, the calculation for the part of the vertical above the connection is the same as under 1, and for the lower part of the vertical beneath the connection, the same as under 2.

For the rest the calculation is as under 1.

## II. SYSTEM OF ISOSCELES BRACING.

*(Load Permanent and Equally Distributed.)*a. *Single System* (triangular truss).

Plate 19,] 1. A loaded apex at the centre. (Fig. 111.)

Fig. 111.] The number of panels extended as occasion requires.

In general, each pair of diagonals from centre to abutment increases by  $W \cdot \frac{d}{h}$  (i. e.,  $W \sec \alpha$ ).

112.] 2. An unloaded apex at the centre. (Fig. 112.)

Each pair of diagonals from centre to abutment increases by  $W \cdot \frac{d}{h}$ .

When each diagonal represents one panel =  $b$ , and the number of panels =  $n$  for one-half of the truss, counting from centre to abutment, there results the strain in flanges for an even 113,]  $n$ , say  $n = 6$ , and a loaded apex at the centre (Fig. 113), or 114.] an unloaded apex at the centre (Fig. 114).

For an uneven  $n$ , say  $n = 7$ , and a loaded apex at the centre 115,] (see Fig. 115); and for an uneven  $n$ , say  $n = 7$ , but an un- 116.] loaded apex at the centre (see Fig. 116).

b. *Combined System* (isometrical truss).117.] A loaded apex at the centre, and  $n = 6$  (Fig. 117).

For a full load in the  $x$ th panel the tension in the tie-rod or  $D_x = + x \cdot \frac{W}{4} \cdot \frac{d}{h}$ , and the compression of diagonal,  $D_x = - (x - 1) \frac{W}{4} \cdot \frac{d}{h}$ .

The strains for this figure (where  $n = 6$ ) will also be obtained by laying the figures 113 and 114 (A and B) together, making there  $\frac{W}{4}$ , instead of  $\frac{W}{2}$ , and adding the strains in flanges where they cover each other.

[Plates 18 and 19—embracing Figs. 108 to 117.]

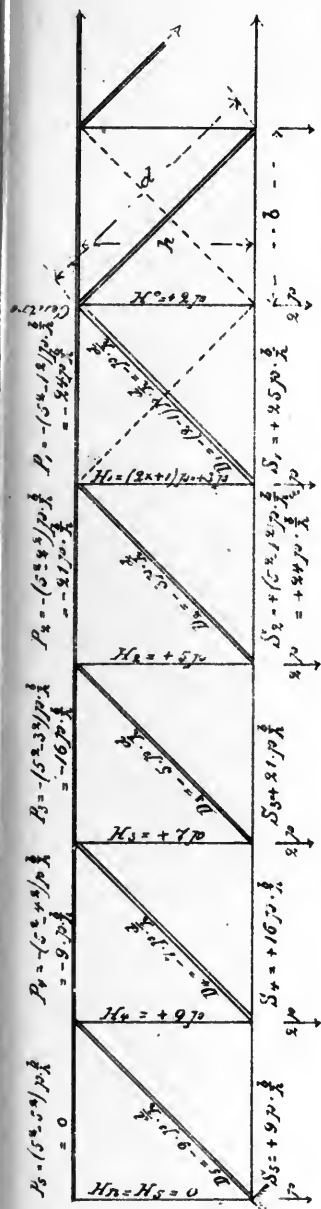


Fig. 108

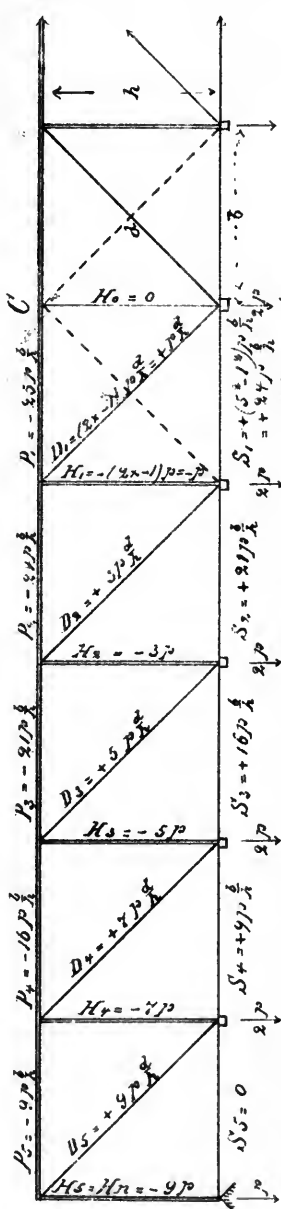


Fig. 109

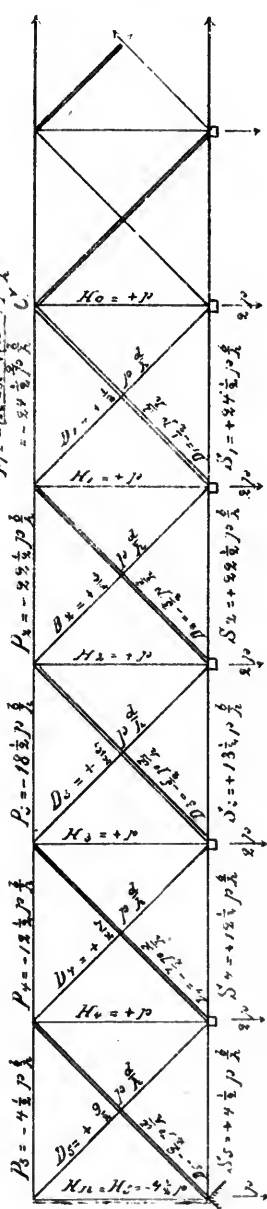
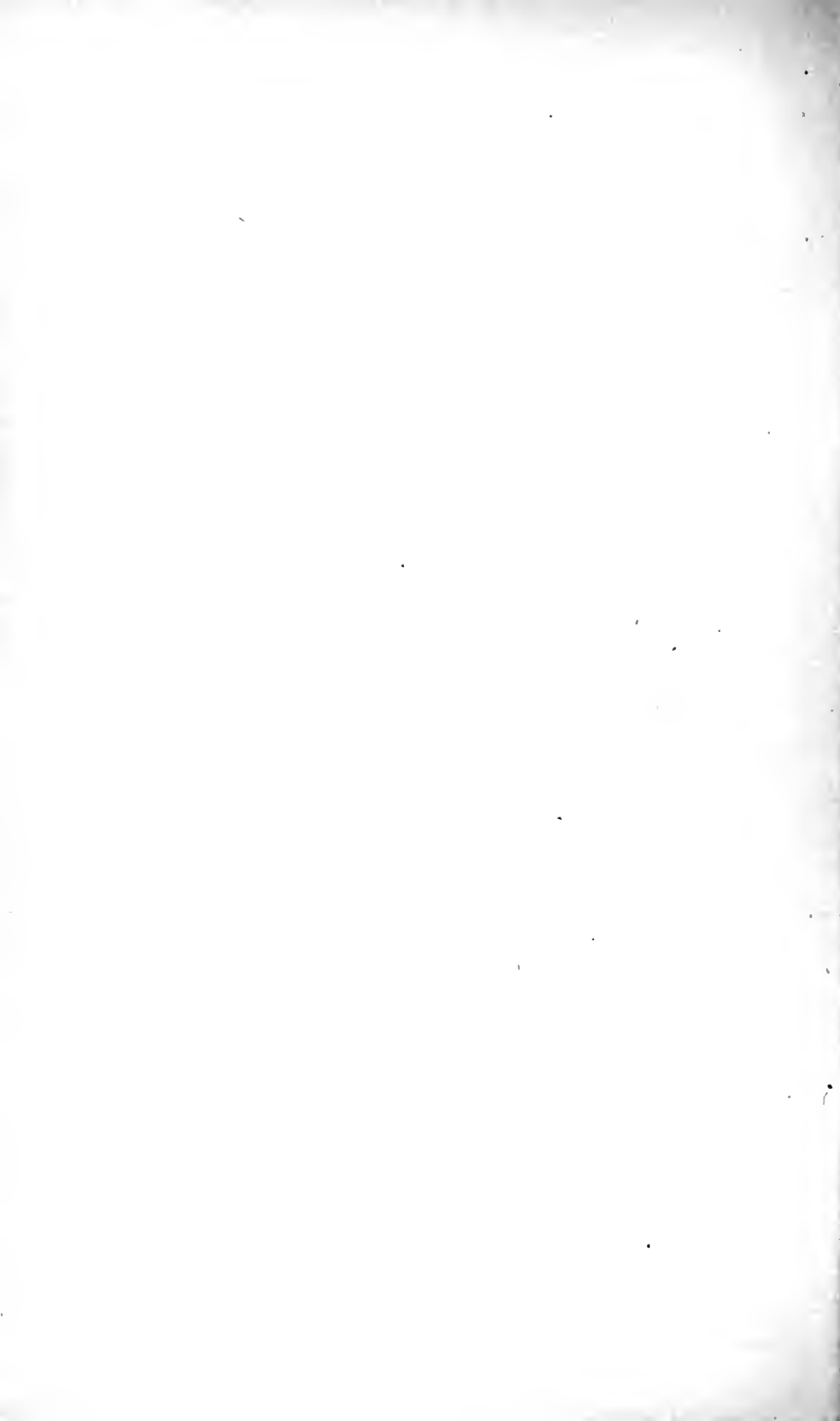


Fig. 110





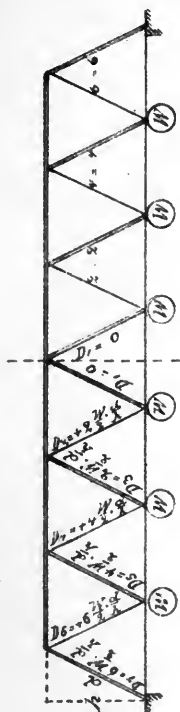


fig. 112

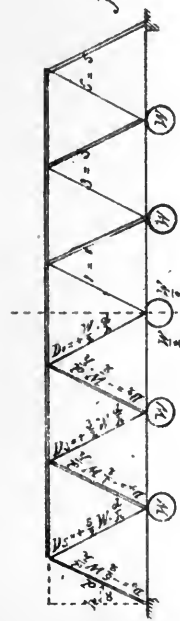


fig. 113

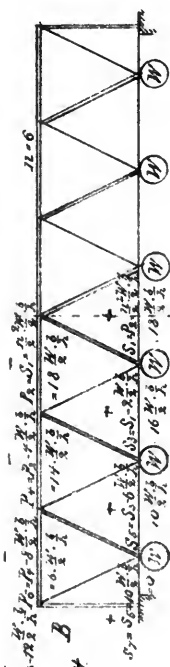


fig. 114

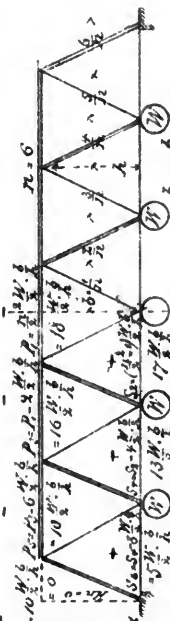


fig. 115

fig. 116

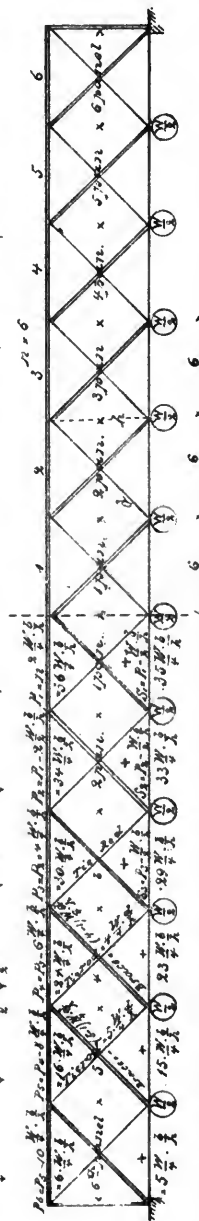
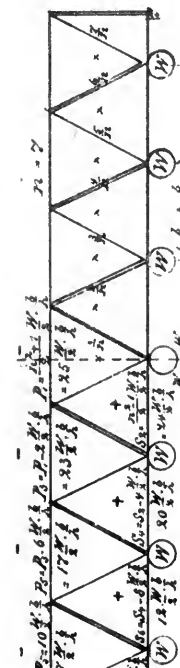
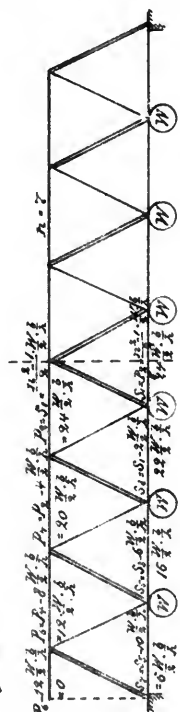


fig. 117



## SECTION II.

### GIRDERS CALCULATED FOR COMBINED (PERMANENT AND ROLLING) LOAD.

#### A. GIRDERS WITH PARALLEL TOP AND BOTTOM FLANGES.

##### I. *THE RIGHT-ANGLED SYSTEM.*

For the strain in flanges I refer to the preceding. It needs no repetition, as the strain in flanges is the largest for a full (permanent) load. (Figs. 108 to 117.)

As mentioned at the close of Sect. I. (General Remarks), the influence of a rolling load upon braces and tie-rods is very essential, and it is greatest when a traversing train of uniform density reaches the centre of the bridge.

For explanation we choose the diagonal  $y_3$  in Fig. Plate 20,] 118.  $q$  is the rolling load (traversing train) for one  
Fig. 118.] panel;  $p$  is the permanent load (weight of structure);  
so, again, is (see Figs. 81 and 94),

$$0 = -y_3 \cdot \sin \varphi - D \cdot \infty + \left( \frac{p}{2} + \frac{q}{2} \right) \infty + (p+q) \infty + (p+q) \infty,$$

$$\text{or I. } 0 = -y_3 \cdot \sin \varphi - D + (p+q) + (p+q) + \left( \frac{p}{2} + \frac{q}{2} \right) \\ (\text{rot. } r. o).$$

As before,  $y_3 \cdot \sin \varphi$  is the vertical component of  $y_3$ , and  $D$  is the reaction of abutment, or

$$D_1 = (p+q) \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \frac{7}{8} + \frac{8}{8} \right). \quad (\text{Fig. 119.})$$

$$\text{II. } D = (p+q) \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \frac{7}{8} \right). \quad (\text{See Fig. 89.})$$

We include the value of  $D_1$  in Equation I., so that the influence

of each fraction of rolling load and permanent load upon  $D$  may be visible in its proper place.

$$\text{III. } 0 = -y_3 \cdot \sin \varphi - (p+q) \left[ \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} \right) + \left( \frac{6}{8} - 1 \right) + \left( \frac{7}{8} - 1 \right) + \left( \frac{8}{8} - \frac{1}{2} \right) \right],$$

$$\text{or } 0 = -y_3 \cdot \sin \varphi - (p+q) \left[ \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} \right) - \left( 1 - \frac{6}{8} \right) - \left( 1 - \frac{7}{8} \right) \right];$$

and now, separating the members containing the permanent load,  $p$ , from those containing the rolling load,  $q$ , and separating also the positive and negative members of the movable load,

$$0 = -y_3 \cdot \sin \varphi - p \left[ \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} - \left( 1 - \frac{6}{8} \right) - \left( 1 - \frac{7}{8} \right) \right]; \\ - q \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} \right) + q \left[ \left( 1 - \frac{6}{8} \right) + \left( 1 - \frac{7}{8} \right) \right].$$

In this equation may be neglected at one time the positive part, and at another time the negative part, of the movable load,  $q$ , and the maximum and minimum strain for  $y$  will be obtained, viz.:

$$\text{I. } 0 = -y_3 \cdot \sin \varphi - p \left( \frac{15}{8} - \frac{2}{8} - \frac{1}{8} \right) - q \cdot \frac{15}{8} \text{ (max. compr.)}.$$

$$\text{II. } 0 = -y_3 \cdot \sin \varphi - p \left( \frac{15}{8} - \frac{2}{8} - \frac{1}{8} \right) + q \left( \frac{2}{8} + \frac{1}{8} \right) \text{ (min. compr.)},$$

or when the factor of  $q$  is greater than the factor of  $p$ , then it will be the maximum tension in this diagonal.

In Equation III. the fraction to the right is

$$(p+q) \left( \frac{4}{8} - \frac{1}{2} \right) = 0;$$

120.] therefore we introduce again  $D$  instead of  $D_1$ , and find from

Fig. 120, under the same supposition of  $x = \infty$  for the vertical rod  $V_2$ ,

$$0 = +V_2 \infty - D \infty + (p+q) \infty,$$

$$\text{or } 0 = +V_2 - D + (p+q) + (p+q),$$

differing from the equation for  $y$  only in so far as here is  $V$  instead of  $-y \sin \varphi$ .

*Example.*—Calculation of diagonals and verticals for a combined load:

121.] Length of truss = 48 feet; (Fig. 121.)

8 panels, each 6 feet =  $l$ ;

height = 6 feet =  $h$ ;

permanent load = 3000 lbs. per panel =  $p$ ;

rolling load = 15000 lbs. per panel =  $q$ .

The load being connected to the lower apexes, the pressure,  $D$ , of supports from Fig. 89 = 63000 lbs.

122.] Fig. 122 gives the equations,

$$0 = -y_1 \cdot \sin 45 - D \text{ (rot. } r.o.);$$

$$0 = -y_1 \cdot 0,7 - 63000;$$

or 
$$y_1 = -\frac{63000}{0,7} = -90000.$$

123.] From Fig. 123 we have

$$0 = -y_2 \cdot 0,7 - D + (p + q),$$

and including  $D$  combined with  $p + q$  on its proper place,

$$0 = -y_2 \cdot 0,7 - (p + q) \left[ \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \left( \frac{7}{8} - 1 \right) \right],$$

or  $0 = -y_2 \cdot 0,7 - (p + q) \left[ \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} - \left( 1 - \frac{7}{8} \right) \right];$

$$0 = -y_2 \cdot 0,7 - p \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} - \frac{1}{8} \right) - q \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} \right) - q \left( -\frac{1}{8} \right);$$

$$0 = -y_2 \cdot 0,7 - p \cdot \frac{2,9}{8} - q \cdot \frac{2,1}{8} + q \cdot \frac{1}{8},$$

and from this the two equations,

1.)  $0 = -y_2 \cdot 0,7 - p \cdot \frac{2,9}{8} - q \cdot \frac{2,1}{8}, \quad \text{or } y_2 \cdot 0,7 = -3000 \times \frac{2,9}{8} - 15000 \times \frac{2,1}{8}.$

2.)  $0 = -y_2 \cdot 0,7 - p \cdot \frac{2,9}{8} + q \cdot \frac{1}{8}, \quad \text{or } y_2 \cdot 0,7 = -3000 \times \frac{2,9}{8} + 15000 \times \frac{1}{8}.$

I.  $y_2 = -66964 \text{ (max. compr.)};$

II.  $y_2 = -8036 \text{ (min. compr.)}.$

124.] Fig. 124 gives

$$0 = -y_3 \cdot 0,7 - D + (p + q) + (p + q);$$

$$0 = -y_3 \cdot 0,7 - (p + q) \left[ \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \left( \frac{6}{8} - 1 \right) + \left( \frac{7}{8} - 1 \right) \right];$$

$$0 = -y_3 \cdot 0,7 - (p + q) \left[ \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} - \left( 1 - \frac{6}{8} \right) - \left( 1 - \frac{7}{8} \right) \right];$$

$$0 = -y_3 \cdot 0,7 - (p + q) \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} - \frac{2}{8} - \frac{1}{8} \right);$$

$$0 = -y_3 \cdot 0,7 - p \cdot \frac{1,2}{8} - q \cdot \frac{1,5}{8} + q \cdot \frac{3}{8};$$

1.)  $0 = -y_3 \cdot 0,7 - p \cdot \frac{1,2}{8} - q \cdot \frac{1,5}{8};$

2.)  $0 = -y_3 \cdot 0,7 - p \cdot \frac{1,2}{8} + q \cdot \frac{3}{8}.$

$$\text{I. } y_3 = -46608;$$

$$\text{II. } y_3 = +1608.$$

For further equations, sketches will not be necessary, and they may be written in reduced forms.

$$0 = -y_4 \cdot 0,7 - D + (p + q) + (p + q) + (p + q);$$

$$0 = -y_4 \cdot 0,7 - (p + q) \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} - \frac{3}{8} - \frac{2}{8} - \frac{1}{8} \right);$$

$$0 = -y_4 \cdot 0,7 - p \cdot \frac{4}{8} - q \cdot \frac{1^0}{8} + q \cdot \frac{6}{8}.$$

$$1.) \quad 0 = -y_4 \cdot 0,7 - p \cdot \frac{4}{8} - q \cdot \frac{1^0}{8};$$

$$2.) \quad 0 = -y_4 \cdot 0,7 - p \cdot \frac{4}{8} + q \cdot \frac{6}{8}.$$

$$\text{I. } y_4 = +13930;$$

$$\text{II. } y_4 = -28930.$$

$$0 = -y_5 \cdot 0,7 - D + (p + q) + (p + q) + (p + q) + (p + q) + (p + q);$$

$$0 = -y_5 \cdot 0,7 - (p + q) \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} - \frac{4}{8} - \frac{3}{8} - \frac{2}{8} - \frac{1}{8} \right);$$

$$0 = -y_5 \cdot 0,7 + p \cdot \frac{4}{8} - q \cdot \frac{6}{8} + q \cdot \frac{1^0}{8}.$$

$$1.) \quad 0 = -y_5 \cdot 0,7 + p \cdot \frac{4}{8} - q \cdot \frac{6}{8};$$

$$2.) \quad 0 = -y_5 \cdot 0,7 + p \cdot \frac{4}{8} + q \cdot \frac{1^0}{8}.$$

$$\text{I. } y_5 = -13930;$$

$$\text{II. } y_5 = +28930.$$

$$0 = -y_6 \cdot 0,7 - (p + q) \left( \frac{1}{8} + \frac{2}{8} - \frac{5}{8} - \frac{4}{8} - \frac{3}{8} - \frac{2}{8} - \frac{1}{8} \right);$$

$$0 = -y_6 \cdot 0,7 + p \cdot \frac{1^2}{8} - q \cdot \frac{3}{8} + q \cdot \frac{1^5}{8}.$$

$$1.) \quad 0 = -y_6 \cdot 0,7 + p \cdot \frac{1^2}{8} - q \cdot \frac{3}{8};$$

$$2.) \quad 0 = -y_6 \cdot 0,7 + p \cdot \frac{1^2}{8} + q \cdot \frac{1^5}{8}.$$

$$\text{I. } y_6 = -1608;$$

$$\text{II. } y_6 = +46608.$$

$$0 = -y_7 \cdot 0,7 - (p + q) \left( \frac{1}{8} - \frac{6}{8} - \frac{5}{8} - \frac{4}{8} - \frac{3}{8} - \frac{2}{8} - \frac{1}{8} \right);$$

$$0 = -y_7 \cdot 0,7 + p \cdot \frac{2^0}{8} - q \cdot \frac{1}{8} + q \cdot \frac{2^1}{8}.$$

$$1.) \quad 0 = -y_7 \cdot 0,7 + p \cdot \frac{2^0}{8} - q \cdot \frac{1}{8};$$

$$2.) \quad 0 = -y_7 \cdot 0,7 + p \cdot \frac{2^0}{8} + q \cdot \frac{2^1}{8}.$$

$$\text{I. } y_7 = + 8036;$$

$$\text{II. } y_7 = + 66964.$$

$$0 = -y_3 \cdot 0,7 - (p + q) \left( -\frac{7}{8} - \frac{9}{8} - \frac{5}{8} - \frac{4}{8} - \frac{3}{8} - \frac{2}{8} - \frac{1}{8} \right);$$

$$0 = -y_3 \cdot 0,7 + p \cdot \frac{2^8}{8} + q \cdot \frac{2^8}{8}.$$

$$1.) \ y_3 = \frac{p + q}{0,7} \times \frac{2^8}{8}.$$

$$\text{I. } y_3 = + 90000.$$

In the preceding examples, as already stated, the value of vertical  $V$  can be easily obtained from the strain in the diagonals; so for  $V_3$ , making the character (symbol) reversed.

$$V_3 = + y_3 \cdot 0,7 = 46608 \times 0,7 = + 32625,$$

$$\text{and } V_3 = -y_3 \cdot 0,7 = -1608 \times 0,7 = -1125;$$

but the usual way is here preferable.

$$V_0 = 0;$$

$$V_8 = -63000;$$

and for a deck-bridge would be

$$V_0 = -9000;$$

$$V_8 = -72000.$$

$$125.] \quad 0 = V_1 - D \text{ (rot. } r.o.); \quad (\text{Fig. 125.})$$

$$V_1 = + 63000.$$

$$126.] \quad 0 = V_2 - D + (p + q); \quad (\text{Fig. 126.})$$

$$0 = V_2 - (p + q) \left[ \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \left( \frac{7}{8} - 1 \right) \right];$$

$$0 = V_2 - (p + q) \left[ \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \dots + \frac{6}{8} - \left( 1 - \frac{7}{8} \right) \right];$$

$$0 = V_2 - (p + q) \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \dots + \frac{6}{8} - \frac{1}{8} \right);$$

$$0 = V_2 - p \cdot \frac{2^9}{8} - q \cdot \frac{2^1}{8} + q \cdot \frac{1}{8}.$$

$$1.) \ 0 = V_2 - p \cdot \frac{2^9}{8} - q \cdot \frac{2^1}{8}, \text{ or } V_2 = -3000 \times \frac{2^9}{8} - 15000 \times \frac{2^1}{8};$$

$$2.) \ 0 = V_2 - p \cdot \frac{2^9}{8} + q \cdot \frac{1}{8}, \text{ or } V_2 = 3000 \times \frac{2^9}{8} + 15000 \times \frac{1}{8}.$$

$$\text{I. } V_2 = + 46875 \text{ (max. tension);}$$

$$\text{II. } V_2 = + 5625.$$

$$127.] \quad 0 = V_3 - D + (p + q) + (p + q); \quad (\text{Fig. 127.})$$

$$0 = V_3 - (p + q) \left[ \frac{1}{3} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \left( \frac{6}{8} - 1 \right) + \left( \frac{7}{8} - 1 \right) \right];$$

$$0 = V_3 - (p + q) \left[ \frac{1}{3} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} - \left( 1 - \frac{6}{8} \right) - \left( 1 - \frac{7}{8} \right) \right];$$

$$0 = V_3 - p \left( \frac{1}{3} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} - \frac{3}{8} - \frac{1}{8} \right) - q \left( \frac{1}{3} + \frac{2}{8} + \dots + \frac{5}{8} \right) + q \left( \frac{2}{8} + \frac{1}{8} \right);$$

$$0 = V_3 - p \cdot \frac{1^2}{8} + q \cdot \frac{1^5}{8} - q \cdot \frac{3}{8}.$$

$$1.) \quad 0 = V_3 - p \cdot \frac{1^2}{8} + q \cdot \frac{1^5}{8};$$

$$2.) \quad 0 = V_3 - p \cdot \frac{1^2}{8} - q \cdot \frac{3}{8}.$$

$$\text{I. } V_3 = + 32625 \text{ (max. tension).}$$

$$\text{II. } V_3 = - 1125 \text{ (max. compr.).}$$

$$0 = V_4 - D + (p + q) + (p + q) + (p + q);$$

$$0 = V_4 - (p + q) \left[ \frac{1}{3} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} - \frac{3}{8} - \frac{2}{8} - \frac{1}{8} \right];$$

$$0 = V_4 - p \cdot \frac{4}{8} - q \cdot \frac{1^9}{8} + q \cdot \frac{6}{8}.$$

$$1.) \quad 0 = V_4 - p \cdot \frac{4}{8} - q \cdot \frac{1^9}{8};$$

$$2.) \quad 0 = V_4 - p \cdot \frac{4}{8} + q \cdot \frac{6}{8}.$$

$$\text{I. } V_4 = + 20250;$$

$$\text{II. } V_4 = - 9750.$$

$$0 = V_5 - D + (p + q) + (p + q) + (p + q) + (p + q);$$

$$0 = V_5 - (p + q) \left( \frac{1}{3} + \frac{2}{8} + \frac{3}{8} - \frac{4}{8} - \frac{3}{8} - \frac{2}{8} - \frac{1}{8} \right);$$

$$0 = V_5 + p \cdot \frac{4}{8} - q \cdot \frac{6}{8} + q \cdot \frac{1^9}{8}.$$

$$1.) \quad 0 = V_5 + p \cdot \frac{4}{8} + q \cdot \frac{1^9}{8};$$

$$2.) \quad 0 = V_5 + p \cdot \frac{4}{8} - q \cdot \frac{6}{8}.$$

$$\text{I. } V_5 = - 20250;$$

$$\text{II. } V_5 = + 9750.$$

$$0 = V_6 - (p + q) \left( \frac{1}{3} + \frac{2}{8} - \frac{5}{8} - \frac{4}{8} - \frac{3}{8} - \frac{2}{8} - \frac{1}{8} \right);$$

$$0 = V_6 + p \cdot \frac{1^2}{8} - q \cdot \frac{3}{8} + q \cdot \frac{1^5}{8};$$

$$1.) \quad 0 = V_6 + p \cdot \frac{1^2}{8} - q \cdot \frac{3}{8};$$

$$2.) \quad 0 = V_6 + p \cdot \frac{1^2}{8} + q \cdot \frac{1^5}{8}.$$



fig. 118

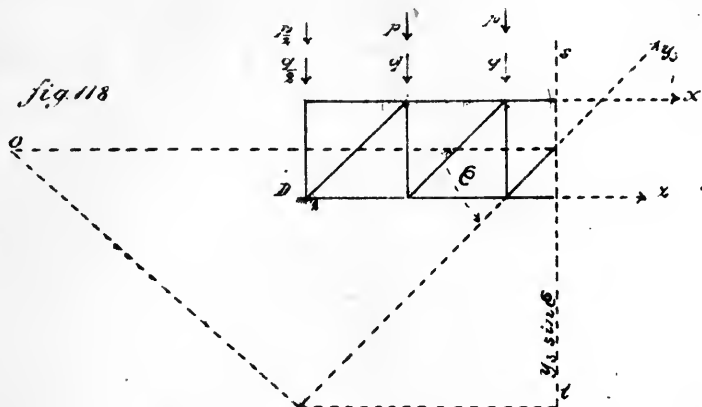


fig. 119

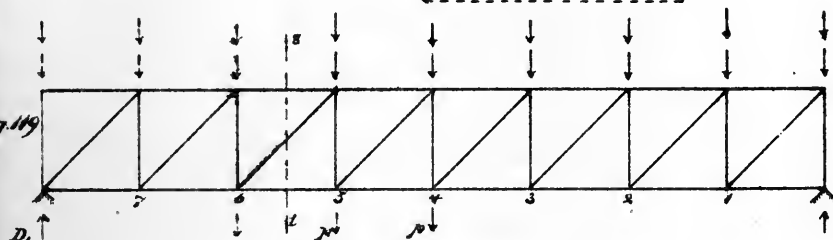


fig. 120

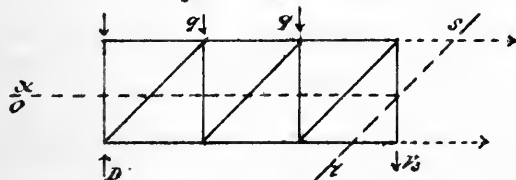


fig. 121

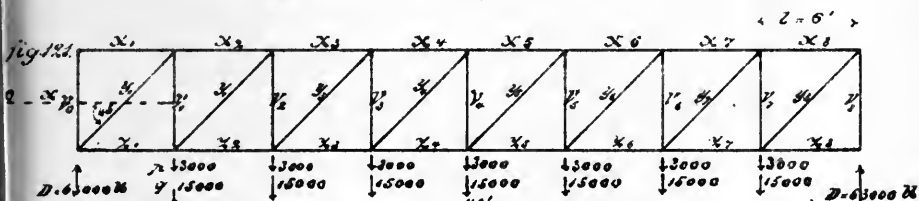


fig. 122

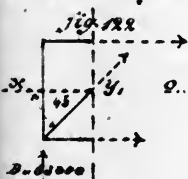


fig. 123

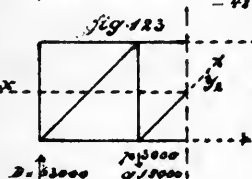


fig. 124

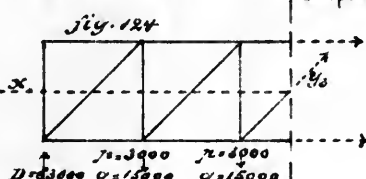


fig. 125

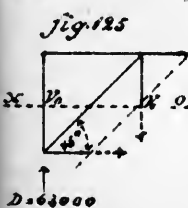


fig. 126

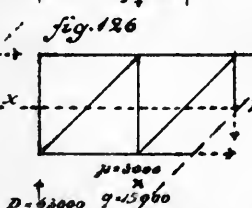
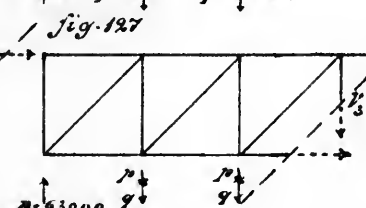


fig. 127





$$\text{I. } V_6 = -32625;$$

$$\text{II. } V_6 = +1125.$$

$$0 = V_7 - (p + q) \left( \frac{1}{8} - \frac{6}{8} - \frac{5}{8} - \frac{4}{8} - \frac{3}{8} - \frac{2}{8} - \frac{1}{8} \right);$$

$$0 = V_7 + p \cdot \frac{29}{8} - q \cdot \frac{1}{8} + q \cdot \frac{21}{8}.$$

$$1.) \quad 0 = V_7 + p \cdot \frac{29}{8} + q \cdot \frac{21}{8};$$

$$2.) \quad 0 = V_7 + p \cdot \frac{29}{8} - q \cdot \frac{1}{8}.$$

$$\text{I. } V_7 = -46875 \text{ (max. compr.)};$$

$$\text{II. } V_7 = -5625.$$

$$0 = V_8 - (p + q) \left( -\frac{7}{8} - \frac{6}{8} - \frac{5}{8} - \frac{4}{8} - \frac{3}{8} - \frac{2}{8} - \frac{1}{8} \right);$$

$$V_8 = -18000 \times \frac{28}{8} = -63000.$$

Plate 21,] The results are combined in the skeleton (Fig. 128);  
Fig. 128.] and the strain in flanges, from the example in Sect. I.,  
D., is repeated.

129.] In the symmetrical skeleton (Fig. 129) the tensile strains  
in the braces are replaced by counter-braces. The verticals  
are exposed only to tensile strain.

130.] In the same way the skeleton can easily be transformed  
to a reversed system (Pratt Truss, Fig. 132); but the uni-  
formity in calculation may here, also, be first shown. (Fig. 130.)

$$V_8 = -D, \text{ or } 0 = -V_8 - (p + q) \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \frac{7}{8} \right);$$

$$V_8 = -(p + q) \frac{28}{8} = -63000.$$

$$131.] \quad 0 = +y_8 \cdot 0,7 - D; \quad (\text{Fig. 131.})$$

$$y_8 = + \frac{63000}{0,7} = 90000.$$

132.] The compressive strains of the diagonals in skeleton 132  
are replaced by counter-rods.

The verticals or posts are only exposed to compressive strain.

For a deck-bridge, as before shown, the only difference in com-  
pression will be in the end-post, which, in Fig. 129 = -9000 lbs.,  
and in Fig. 132 = -72000 lbs.

[Plates 20 and 21—embracing Figs. 118 to 132.]

## II. ISOSCELES BRACING.

## 1. TRIANGULAR TRUSS.

Plate 22,]  
Fig. 133.] In Fig. 133, the load on the bottom is sustained one-half by the lower apexes, and one-half, by means of vertical tie-rods, by the upper apexes, distributing the load on the top and bottom chords to equal parts.

The length = 259 feet;

the number of triangles, 27;

$$\text{the depth} = \frac{18,5}{2} \tan 60^\circ = 9,25 \times 1,73 = 16 \text{ feet.}$$

For a more simple calculation the length of 9,25, or one-half of the side of the triangle, may be called 1, or unit; then

The side of the triangle = 2;

the height = 1,73;

the whole length of girder = 28.

134.] The load and weight being each 5 tons for every connecting point, the position of the acting forces on the girder will be seen in Fig. 134.

For the calculation of horizontal strains,  $x$  and  $z$ , in the upper and lower chords, we have for the section,  $AMN$ , with  $M$  at one time, and  $N$  at another, as the point of rotation, and the value of

$$D = 10 \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{27}{28} \right) = 135 \text{ tons.}$$

The value of  $D = 135$  tons, introduced.

$$135.] \quad 0 = x_4 \cdot 1,73 + 135 \times 7 - 10 (1 + 2 + 3 + \dots + 6); \quad (\text{Fig. 135.})$$

$$0 = -z_4 \cdot 1,73 + 135 \times 8 - 10 (1 + 2 + 3 + \dots + 7).$$

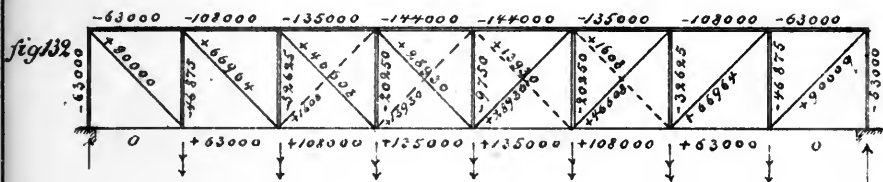
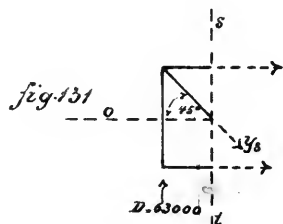
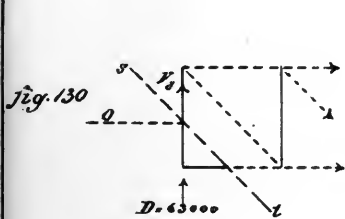
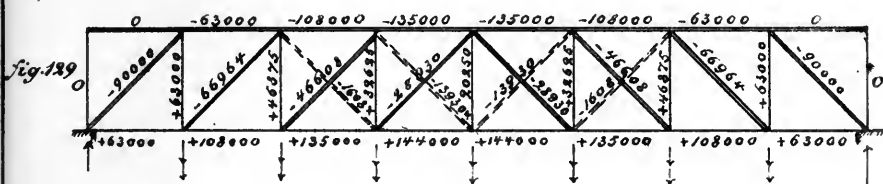
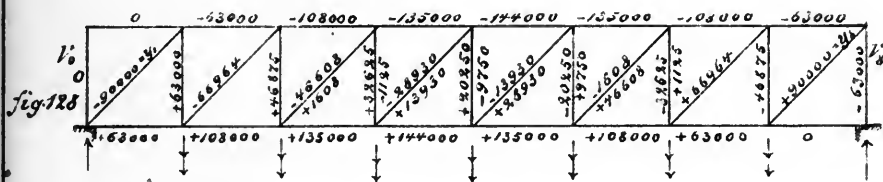
These equations give the result,

$$x_4 = -425 \text{ tons;}$$

$$z_4 = +462 \quad "$$

In the same way for the other strains in  $x$  and  $z$ .

$$0 = x_1 \cdot 1,73 + 135 \times 1;$$





$$x_1 = -78 \text{ tons.}$$

$$0 = -z_1 \cdot 1.73 + 135 \times 2 - 10.1;$$

$$z_1 = +150 \text{ tons.}$$

$$0 = x_2 \cdot 1.73 + 135 \times 3 - 10(1+2);$$

$$x_2 = -216 \text{ tons.}$$

$$0 = -z_2 \cdot 1.73 + 135 \times 4 - 10(1+2+3);$$

$$z_2 = +277 \text{ tons;}$$

$$0 = x_3 \cdot 1.73 + 135 \times 5 - 10(1+2+3+4);$$

$$x_3 = -338 \text{ tons;}$$

$$0 = -z_3 \cdot 1.73 + 135 \times 6 - 10(1+2+3+4+5);$$

$$z_3 = +381 \text{ tons.}$$

Further, also,

$$x_5 = -494 \text{ tons;}$$

$$z_5 = +520 \quad "$$

$$x_6 = -540 \quad "$$

$$z_6 = +555 \quad "$$

$$x_7 = -564 \quad "$$

$$z_7 = +566 \quad "$$

*Remark.*—For an approximate calculation of strain in the top and bottom flanges at the centre, when  $10 \times 28 =$  entire load, or  $140 =$  one-half of the load,

$$\frac{140 \times \frac{28}{4}}{1.73} = 566 \text{ tons.}$$

#### CALCULATION OF STRAINS $y$ AND $u$ IN DIAGONALS.

The angle of diagonals with a horizontal line being  $60^\circ$ , for the strain in diagonals and tie-rods we have

$$y \cdot \sin 60^\circ, \quad \text{and } u \cdot \sin 60^\circ,$$

$$\text{or} \quad y \cdot 0.866, \quad \text{and } u \cdot 0.866.$$

136,] So for  $y_4$  and  $u_4$  in Figs. 136 and 137,  
137.]

$$o = y_4 \cdot 0,866 - D + 5 \times 6 + 5 \times 6;$$

$$o = -u_4 \cdot 0,866 - D + 5 \times 7 + 5 \times 7.$$

In substituting the permanent and rolling load,

$$D = 5 \left( \frac{1}{28} + \frac{2}{28} + \frac{3}{28} + \dots + \frac{27}{28} \right) + 5 \left( \frac{1}{28} + \frac{2}{28} + \frac{3}{28} \dots + \frac{27}{28} \right);$$

and combining each time the share of each separate load of the pressure,  $D$ , with those directly-produced vertical strains, as in the Howe truss already shown, these equations will be

$$0 = y_4 \cdot 0,866 - 5 \left[ \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{27}{28} \right) - \left( 1 - \frac{22}{28} \right) - \left( 1 - \frac{23}{28} \right) - \dots \left( 1 - \frac{27}{28} \right) \right] - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{27}{28} \right)$$

$$+ 5 \left[ \left( 1 - \frac{22}{28} \right) + \left( 1 - \frac{23}{28} \right) + \dots \left( 1 - \frac{27}{28} \right) \right];$$

$$0 = -u_4 \cdot 0,866 - 5 \left[ \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{28}{28} \right) - \left( 1 - \frac{21}{28} \right) - \left( 1 - \frac{22}{28} \right) - \dots \left( 1 - \frac{27}{28} \right) \right] - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{28}{28} \right)$$

$$+ 5 \left[ \left( 1 - \frac{21}{28} \right) + \left( 1 - \frac{22}{28} \right) + \dots \left( 1 - \frac{27}{28} \right) \right];$$

and omitting in these equations at one time the positive (+) members and at another time the negative (—) members which were produced by the rolling load, we have

$$0 = y_4 \cdot 0,866 - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{21}{28} - \frac{6}{28} - \frac{5}{28} - \frac{4}{28} - \dots - \frac{1}{28} \right) + 5 \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{21}{28} \right);$$

$$y_4 = + 91 \text{ tons (max.)};$$

$$0 = y_4 \cdot 0,866 - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{21}{28} - \frac{6}{28} - \frac{5}{28} - \dots - \frac{1}{28} \right) + 5 \left( \frac{6}{28} + \frac{5}{28} + \dots + \frac{1}{28} \right);$$

$$y_4 = + 39 \text{ tons.}$$

$$0 = -u_4 \cdot 0,866 - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{20}{28} - \frac{7}{28} - \frac{6}{28} - \dots - \frac{1}{28} \right) + 5 \left( \frac{7}{28} + \frac{6}{28} + \dots + \frac{1}{28} \right);$$

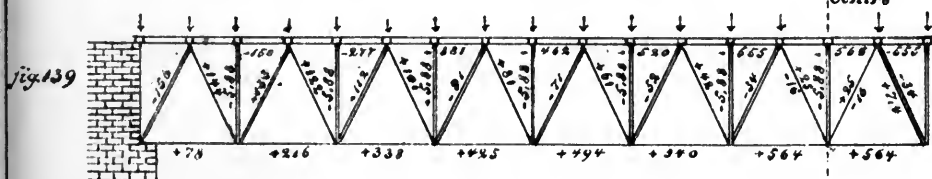
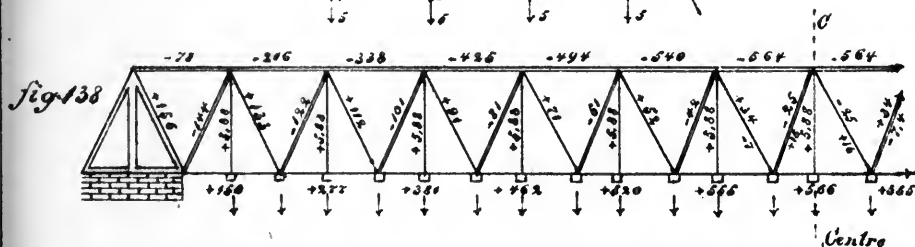
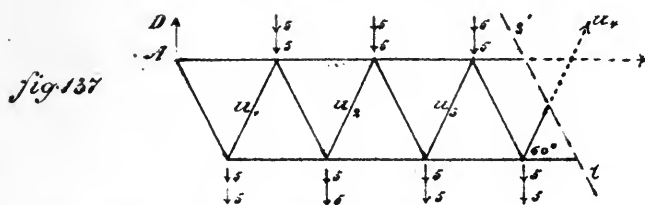
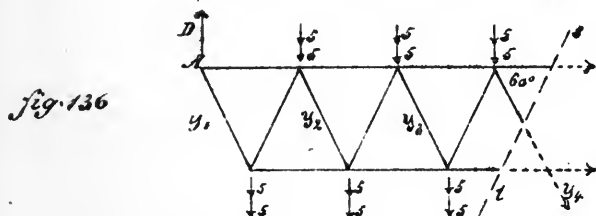
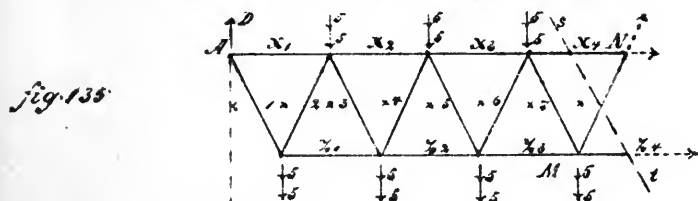
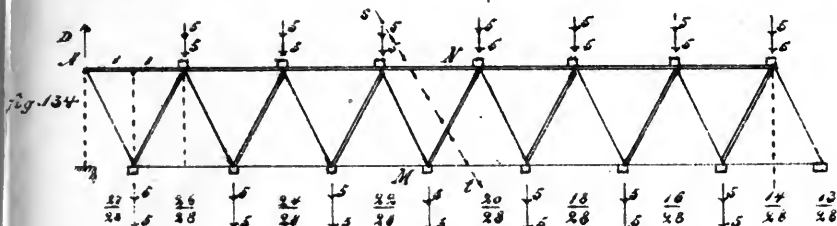
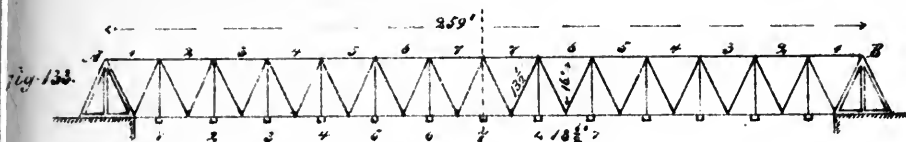
$$u_4 = - 32 \text{ tons.}$$

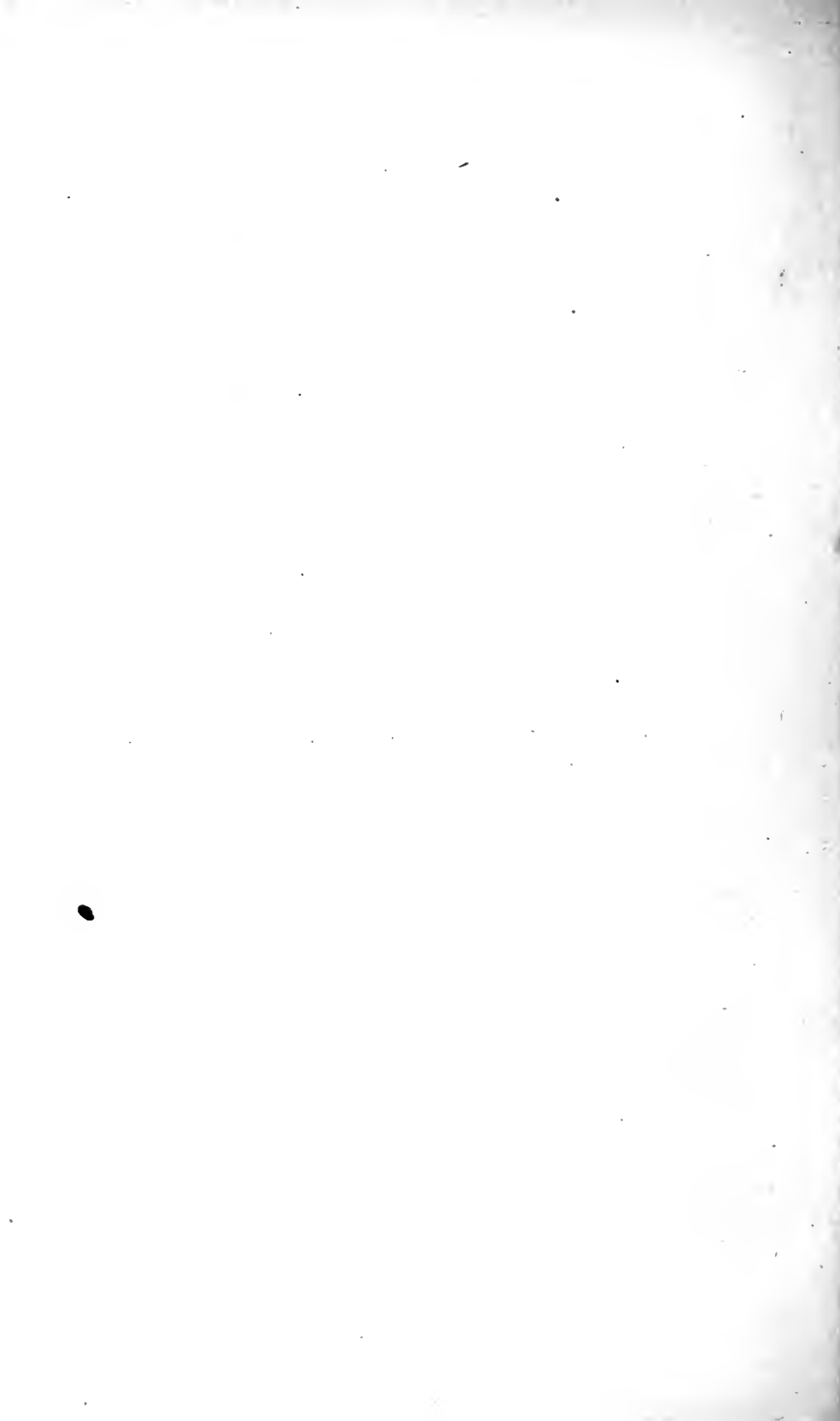
$$0 = -u_4 \cdot 0,866 - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{20}{28} - \frac{7}{28} - \frac{6}{28} - \dots - \frac{1}{28} \right) - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots + \frac{20}{28} \right);$$

$$u_4 = - 81 \text{ tons (min.).}$$

In the same manner as for  $y_4$  and  $u_4$  the equations for the other diagonals are,







$$0 = y_1 \cdot 0,866 - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots \frac{27}{28} \right) - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots \frac{27}{28} \right);$$

$$y_1 = +156 \text{ tons,} \quad \text{and } y_1 = +78 \text{ tons.}$$

$$0 = -u_1 \cdot 0,866 - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots \frac{26}{28} - \frac{1}{28} \right) - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots \frac{26}{28} \right) + 5 \left( \frac{1}{28} \right);$$

$$u_1 = -72 \text{ tons,} \quad \text{and } u_1 = -144 \text{ tons.}$$

$$0 = y_2 \cdot 0,866 - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots \frac{25}{28} - \frac{2}{28} - \frac{1}{28} \right) - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots \frac{25}{28} \right) + 5 \left( \frac{2}{28} + \frac{1}{28} \right);$$

$$y_2 = +133 \text{ tons,} \quad \text{and } y_2 = +66 \text{ tons;}$$

$$0 = -u_2 \cdot 0,866 - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots \frac{24}{28} - \frac{3}{28} - \frac{2}{28} - \frac{1}{28} \right) - 5 \left( \frac{1}{28} + \frac{2}{28} + \dots \frac{24}{28} \right) + 5 \left( \frac{3}{28} + \frac{2}{28} + \frac{1}{28} \right);$$

$$u_2 = -59 \text{ tons,} \quad \text{and } u_2 = -122 \text{ tons.}$$

Further,

$$y_3 = +112, \quad \text{and } y_3 = +53;$$

$$u_3 = -46, \quad \text{and } u_3 = -101;$$

$$y_5 = +71, \quad \text{and } y_5 = +24;$$

$$u_5 = -17, \quad \text{and } u_5 = -61;$$

$$y_6 = +52, \quad \text{and } y_6 = +9;$$

$$u_6 = -0,8, \quad \text{and } u_6 = -42;$$

$$y_7 = +34, \quad \text{and } y_7 = -7,4;$$

$$u_7 = +16, \quad \text{and } u_7 = -25.$$

For the other half of the truss the numbers are the same.

The suspenders bear, besides 5 tons moving load, a part of the permanent load; so that, when the weight of track = 24,75 tons, there is for each rod  $\frac{24,75}{28} = 0,88$  tons more, or 5,88 tons.

138.] The results of the above calculations in skeleton 138.

139.] When the + and - signs in this skeleton are changed, it represents a truss for a deck-bridge. The suspenders in this case will be studs.

## 2. ISOMETRICAL TRUSS.

Plate 23,] Calculation of a 143-foot span through bridge. (Fig.  
Fig. 140.) 140.)



and according to the theorem in Sect. II., Fig. 80, the strains in diagonals joining at an unloaded point are of the same numerical amount, but of opposite character.

$$\text{I. } u_4 = + 2,72 \text{ tons (max. tens.)};$$

$$\text{II. } u_4 = + 26,6 \text{ " (max. compr.)}.$$

In the same way,

$$0 = -y_1 \cdot 0,866 - D;$$

$$y_1 = -\frac{52,25}{0,866} = -60;$$

$$u_1 = + 60;$$

$$0 = -y_2 \cdot 0,866 - (p + q) \left[ \frac{1}{11} + \frac{3}{11} + \frac{5}{11} + \frac{7}{11} + \left( \frac{9}{11} - 1 \right) \right];$$

$$0 = -y_2 \cdot 0,866 - p \cdot \frac{14}{11} - q \cdot \frac{16}{11} + q \cdot \frac{2}{11};$$

$$y_2 = -37,4, \quad \text{and } y_2 = -4,41;$$

$$u_2 = +37,4, \quad \text{and } u_2 = +4,41;$$

$$0 = -y_3 \cdot 0,866 - (p + q) \left[ \frac{1}{11} + \frac{3}{11} + \frac{5}{11} + \left( \frac{7}{11} - 1 \right) + \left( \frac{9}{11} - 1 \right) \right];$$

$$0 = -y_3 \cdot 0,866 - p \cdot \frac{3}{11} - q \cdot \frac{9}{11} + q \cdot \frac{6}{11};$$

$$y_3 = -18,3, \quad \text{and } y_3 = +10;$$

$$u_3 = +18,3, \quad \text{and } u_3 = -10;$$

$$0 = -y_5 \cdot 0,866 - (p + q) \left[ \frac{1}{11} + \left( \frac{3}{11} - 1 \right) + \left( \frac{5}{11} - 1 \right) + \left( \frac{7}{11} - 1 \right) + \left( \frac{9}{11} - 1 \right) \right];$$

$$0 = -y_5 \cdot 0,866 + p \cdot \frac{10}{11} - q \cdot \frac{1}{11} + q \cdot \frac{20}{11};$$

$$y_5 = +47,4, \quad \text{and } y_5 = +9,2;$$

$$u_5 = -47,4, \quad \text{and } u_5 = -9,2;$$

$$0 = -y_6 \cdot 0,866 - (p + q) \left[ \left( \frac{1}{11} - 1 \right) + \left( \frac{3}{11} - 1 \right) + \left( \frac{5}{11} - 1 \right) + \left( \frac{7}{11} - 1 \right) + \left( \frac{9}{11} - 1 \right) \right];$$

$$0 = -y_6 \cdot 0,866 - (p + q) \left( -\frac{10}{11} - \frac{8}{11} - \frac{6}{11} - \frac{4}{11} - \frac{2}{11} \right);$$

$$y_6 = +72,1 \text{ tons.}$$

142.] The results for the combined system in skeleton 142.

*Remark.*—For the compression in the vertical posts *o*, *a* and *11.m* on the abutments, we have

$$0,866 \times 72,1 = 62,5 \text{ tons.}$$

And for an approximate estimate of strain at the centre of chords,

$$23 \times 11 = 253 \text{ the entire weight and load of bridge;}$$

$$126,5 = \text{one-half the weight and load;}$$

$$\frac{126,5 \times \frac{143}{4}}{22,52} = 200 \text{ tons.}$$

## b. CALCULATION OF TOP AND BOTTOM CHORDS (FLANGES).

$$143.] \quad 0 = x_1 \cdot 22,52 + D \cdot o \text{ (rot. } r. a, \text{ Fig. 143);}$$

$$x_1 = 0;$$

$$0 = -z_1 \cdot 22,52 + D \cdot 13 \text{ (rot. } r. 1, \text{ Fig. 143);}$$

$$z_1 = \frac{52,27 \times 13}{22,52} = +30,1;$$

$$0 = x_2 \cdot 22,52 + D \cdot 26 \text{ (rot. } r. c, \text{ Fig. 143);}$$

$$x_2 = -\frac{52,27 \times 26}{22,52} = -60,3;$$

$$0 = -z_2 \cdot 22,52 + D \cdot 39 - 23 \times 13 \text{ (rot. } r. 3);$$

$$z_2 = +\frac{52,27 \times 39 - 23 \times 13}{22,52} = +77,2;$$

$$144.] \quad 0 = x_3 \cdot 22,52 + D \cdot 52 - 23 \times 26 \text{ (rot. } r. e, \text{ Fig. 144);}$$

$$x_3 = -\frac{52,27 \times 52 + 23 \times 26}{22,52} = -94,1;$$

$$145.] \quad 0 = -z_3 \cdot 22,52 + D \cdot 65 - 23 (13 + 39) \text{ (rot. } r. 5, \text{ Fig. 145);}$$

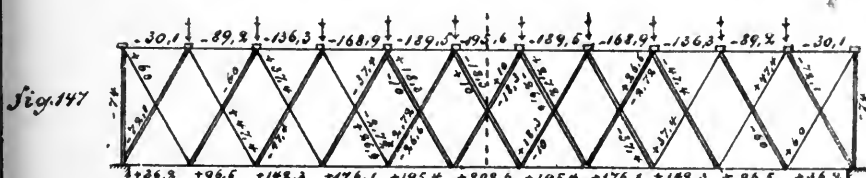
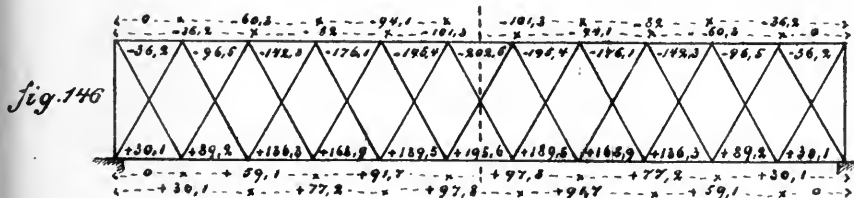
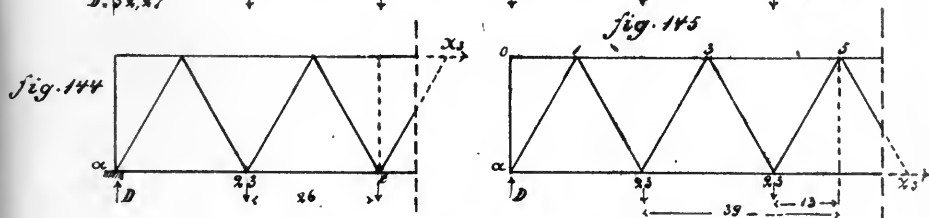
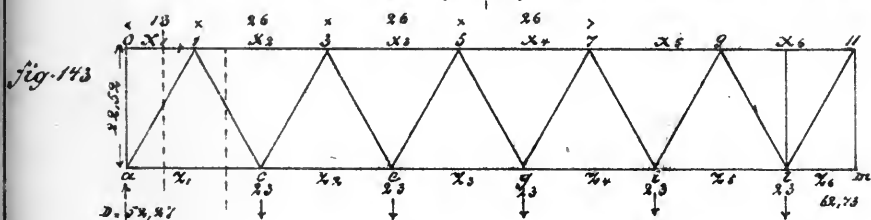
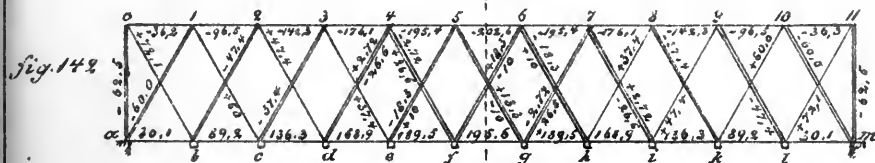
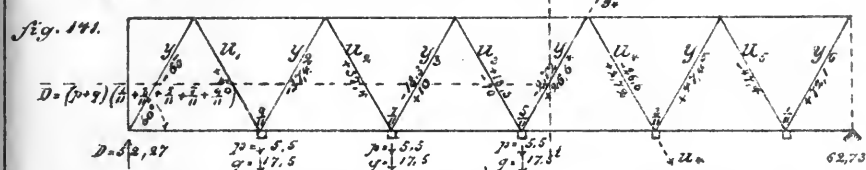
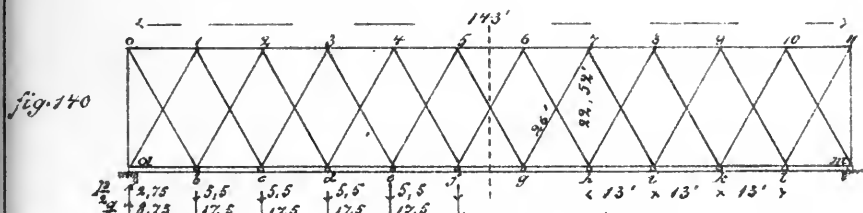
$$z_3 = \frac{52,27 \times 65 - 23 \times 52}{22,52} = +97,8;$$

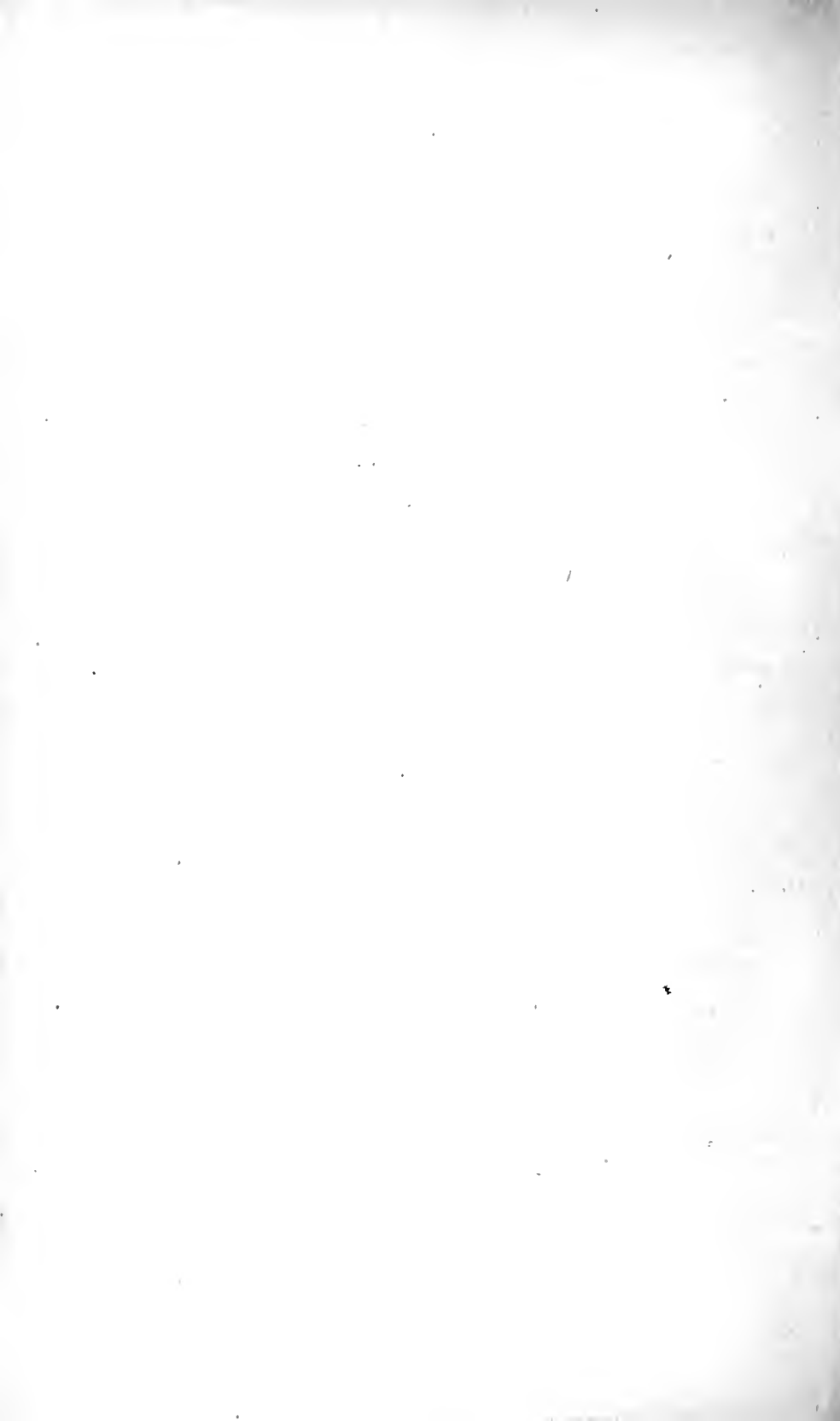
$$0 = x_4 \cdot 22,52 + D \cdot 78 - 23 (26 + 52) \text{ (rot. } r. g);$$

$$x_4 = -\frac{52,27 \times 78 + 23 \times 78}{22,52} = -101,3;$$

$$0 = -z_4 \cdot 22,52 + D \cdot 91 - 23 (13 + 39 + 65) \text{ (rot. } r. 7);$$

$$z_4 = \frac{52,27 \times 91 - 23 \times 117}{22,52} = +91,7;$$







$$0 = x_5 \cdot 22,52 + D \cdot 104 - 23 (26 + 52 + 78) \text{ (rot. r. i)};$$

$$x_5 = - \frac{52,27 \times 104 + 23 \times 156}{22,52} = -82,0;$$

$$0 = -z_5 \cdot 22,52 + D \cdot 117 - 23 (13 + 39 + 65 + 91);$$

$$z_5 = \frac{52,27 \times 117 - 23 \times 208}{22,52} = +59,1;$$

$$0 = x_6 \cdot 22,52 + D \cdot 130 - 23 (26 + 52 + 78 + 104)$$

$$x_6 = - \frac{52,27 \times 130 + 23 \times 260}{22,52} = -36,2;$$

$$0 = -z_6 \cdot 22,52 + D \cdot 143 - 23 (13 + 39 + 65 + 91 + 117);$$

$$z_6 = \frac{52,27 \times 143 - 23 \times 325}{22,52} = 0.$$

146.] The results of strain in the top and bottom flanges by the addition of strain for each single system are combined in Fig. 146.

147.] For a deck-bridge the strains in diagonals and flanges result from Fig. 147.

## B. CAMBER IN TRUSSES, WITH PARALLEL TOP AND BOTTOM CHORDS.

After the definition of the resulting strains, it is a matter of importance to prevent deflection, which should be provided for in "laying out" the truss.

In the suspension truss (Fig. 10) no special attention to certain camber is required, each pair of tie-rods with combined vertical post forming an independent system, regulated by tie-bolts at the foot of the post.

Plate 24,]  
Fig. 148.] In other trusses the difference in the length of diagonals and verticals would form arch-shaped chords, as demonstrated by Fig. 148<sup>a, b</sup>.

This arrangement having some difficulties on account of the difference in the length of braces, another and better plan is fre-

quently adopted in making the division of panels in the bottom chord smaller than in the top chord.

149<sup>a</sup>.] In this case the vertical connections will lose their parallel direction and intersect at a certain point in the vertical centre line. (Fig. 149.)

Approximately, this can be done by experience, though not sufficiently, in case a certain camber is prescribed.

For a correct calculation the annexed tables, showing the length of arches for degrees, minutes and seconds, will be useful. (See Tables, p. 77, *et seq.*)

*Example.*—(Truss, Fig. 140.)

Distance of the distinguished points  $AB = 143$  feet;

depth of truss  $= 22,52$  feet;

number of panels  $= 11$ .

First we find the radius in Fig. 149<sup>a</sup>, according to Sect. I., Fig. B,

The distance  $AB$  being  $2 \times 71,5 = 143$  feet;

the distance  $CI = \frac{AD^2}{CD} + CD,$

$$\text{or} \quad CI = \frac{71,5^2}{0,33333} + 0,33333;$$

$$\text{Diameter } CI = 15336,09 + 0,33333 = 15336,423;$$

$$\text{“} \quad EH = 15336,423 + 2 \times 22,52 = 15381,463;$$

$$\text{or, also,} \quad \text{radius } AM = 7668,211 \text{ feet};$$

$$\text{“} \quad FM = 7690,731 \text{ “}$$

By means of the radii for a small camber ( $\frac{1}{500}$  of the length), in general the difference of length of the top and bottom flanges may be derived approximately by the difference of the chords  $AB$  and  $FG$ , viz.:

$$\frac{Fd}{AD} = \frac{FM}{AM}, \quad \text{or } Fd = AD \cdot \frac{FM}{AM};$$

$$Fd = 71,5 \times \frac{7690,731}{7668,211};$$

$$Fd = 71,709;$$

i. e.,

$$FG = 143,418;$$

and when  $AB = 143,000$  subtracted,  
 the difference of chords  $= 0,418 \text{ ft.} = 5,016 \text{ in.}$ ,  
 which, when divided by 11 (*i. e.*, by the number of panels),

$$\frac{5,016}{11} = 0,456 \text{ in.};$$

therefore, for a camber of 4 inches, the top flanges ought to be made 0,456 inches longer than the bottom flanges; the latter being 13 feet, the top flanges ought to be 13 feet and  $\frac{7}{16}$  inches.

For 4 inches camber, a truss of 100 feet length,  $9\frac{1}{2}$  feet depth, and 9 panels, the top flanges ought to be 0,339 inches longer than the bottom flanges.

Also, a truss with 14 panels,  $9\frac{1}{2}$  feet depth,  $5\frac{1}{2}$  feet in bottom flanges, and 5 feet  $6\frac{1}{8}$  inches in top flanges, will have a camber of nearly 6 inches.

A truss of 27 panels, 4 feet depth,  $2\frac{1}{2}$  feet in bottom flanges, and  $\frac{1}{4}$  more in top flanges, will give a camber of nearly 2 inches.

In the preceding calculation the definition of the angle  $a$  at the centre,  $M$ , is avoided, otherwise, by geometrical rule, the arch is in relation to the whole circle as its angle at the centre is to  $360^\circ$ ;

$$\text{i. e.,} \quad \frac{\text{arc}}{2 \cdot r \cdot \pi} = \frac{a}{360^\circ}, \quad \text{or} \quad \frac{\text{arc}}{\text{diam.} \times 3,14} = \frac{a}{360^\circ}.$$

Now, when not the bottom chord,  $AB$ , but for a small camber the arch  $ACB$  is accepted to 143 feet, and the defined diameter of the preceding is retained, being in reality smaller, then

$$\frac{143}{15336,423 \times 3,141} = \frac{a}{360},$$

$$\text{or} \quad a^\circ = \frac{360 \times 143}{15336,423 \times 3,141} = 1,068^\circ = 1^\circ 4,08';$$

therefore for the arch  $ACB = x$ ,

$$\frac{x}{15336,423 \times 3,141} = \frac{1,063}{360},$$

$$\text{or} \quad x = 142,909,$$

and for the arch  $FEG = y$ ,

$$\frac{y}{15381,463 \times 3,141} = \frac{1,068}{360},$$

or  $y = 143,329$ ;

$y - x = 143,329 - 142,909 = 0,420$  feet = 5,04 inches, the difference in the arches, which, divided by 11, (*i. e.*, by the number of panels),

$\frac{5,04}{11} = 0,458$  inches, the difference in the top and bottom flanges, as before.

More accurate still is the following calculation :

$$\frac{AD}{AM} = \sin \frac{a}{2} = \frac{71,5}{7668,211} = 0,009342,$$

which gives by tables of nat. sin., cos., etc.,

$$\frac{a}{2} = 32,117' \text{ (approx.)}, \text{ or } a = 1^{\circ} 4,234' = 1^{\circ} 4' 14''.$$

The annexed tables show

For $1^{\circ}$	the figure	0,017453
" 4'	"	0,001164
" 14''	"	0,000068
		<u>0,018685</u>

which, by multiplication with the radius,  $AM = r$ , gives arc,  $ACB = 0,018685 \times 7668,211 = 143,2805$  feet, and with the radius,  $FM = R$ ,

$$\text{Arc } FEG = 0,018685 \times 7690,731 = 143,7013 \text{ feet.}$$

The difference of arches, therefore,

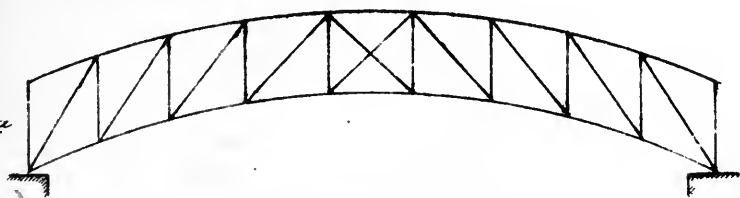
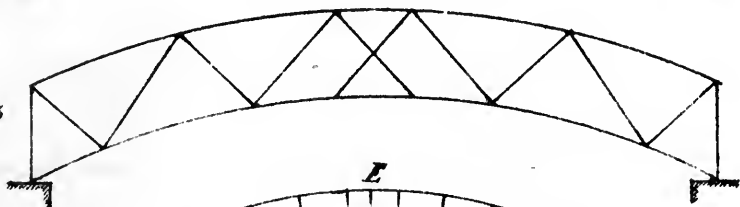
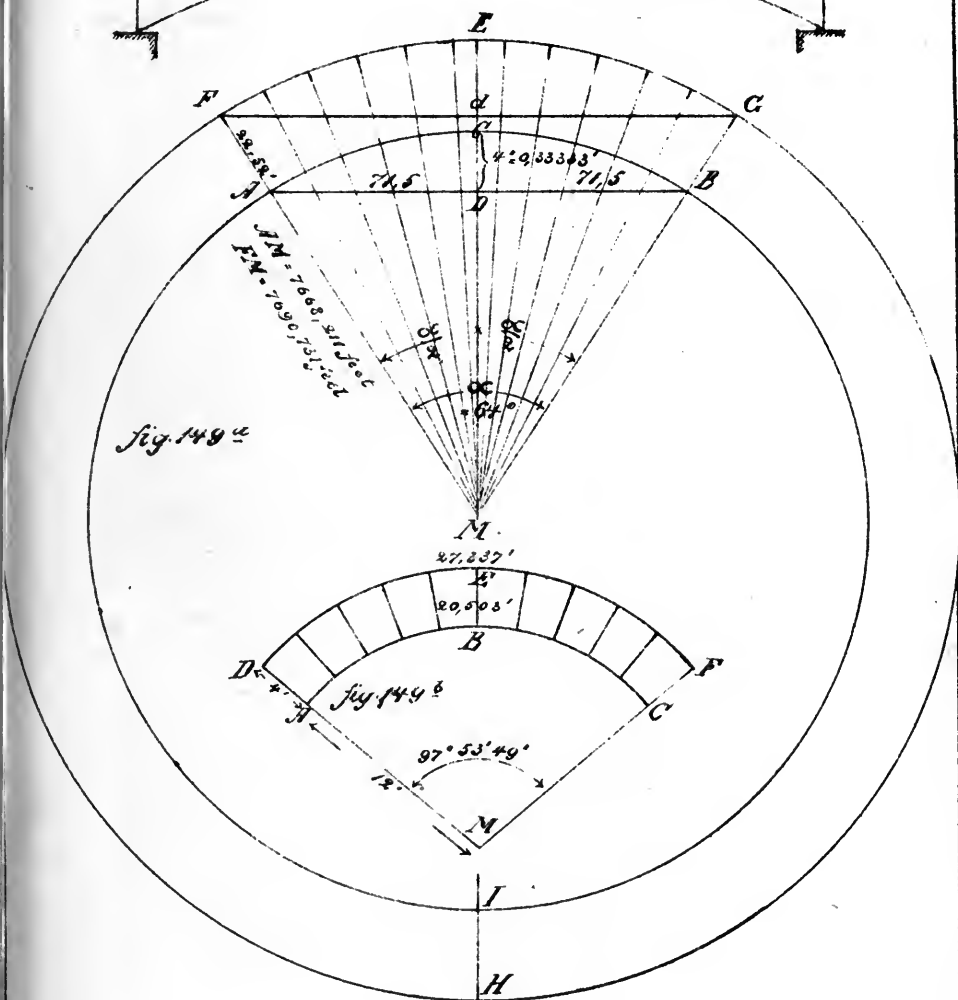
$$143,7013 - 143,2805 = 0,4208 \text{ feet.}$$

This result divided by the number of panels = 11,

$$\frac{0,4208}{11} = 0,038 \text{ feet, or } 0,456 \text{ inches.}$$

Thus  $\frac{143,2805}{11} = 13,025$  feet (the bottom flanges),

and  $13,025 + 0,038 = 13,063$  feet (the top flanges).

fig. 148<sup>a</sup>fig. 148<sup>b</sup>fig. 149<sup>a</sup>



TABLES CONTAINING THE LENGTH OF ARCHES FOR DEGREES, MINUTES AND SECONDS, FOR A RADIUS AS UNIT.

LENGTH OF ARCHES FOR EVERY DEGREE.

1	0.017453	46	0.802852	91	1.588250	136	2.373648	181	3.159046
2	0.034907	47	0.820305	92	1.605703	137	2.391101	182	3.176499
3	0.052360	48	0.837758	93	1.623156	138	2.408554	183	3.193953
4	0.069813	49	0.855211	94	1.640610	139	2.426008	184	3.211406
5	0.087267	50	0.872665	95	1.658063	140	2.443461	185	3.228859
6	0.104720	51	0.890118	96	1.675516	141	2.460914	186	3.246312
7	0.122173	52	0.907571	97	1.692969	142	2.478368	187	3.263766
8	0.139626	53	0.925025	98	1.710423	143	2.495821	188	3.281219
9	0.157080	54	0.942478	99	1.727876	144	2.513274	189	3.298672
10	0.174533	55	0.959931	100	1.745329	145	2.530727	190	3.316126
11	0.191986	56	0.977384	101	1.762783	146	2.548181	191	3.333579
12	0.209440	57	0.994838	102	1.780236	147	2.565634	192	3.351032
13	0.226893	58	1.012291	103	1.797689	148	2.583087	193	3.368486
14	0.244346	59	1.029744	104	1.815142	149	2.600541	194	3.385939
15	0.261799	60	1.047198	105	1.832596	150	2.617994	195	3.403392
16	0.279253	61	1.064651	106	1.850049	151	2.635447	196	3.420845
17	0.296706	62	1.082104	107	1.867502	152	2.652901	197	3.438299
18	0.314159	63	1.099557	108	1.884956	153	2.670354	198	3.455752
19	0.331613	64	1.117011	109	1.902409	154	2.687807	199	3.473205
20	0.349066	65	1.134464	110	1.919862	155	2.705260	200	3.490659
21	0.366519	66	1.151917	111	1.937316	156	2.722714	201	3.508112
22	0.383972	67	1.169371	112	1.954769	157	2.740167	202	3.525565
23	0.401426	68	1.186824	113	1.972222	158	2.757620	203	3.543018
24	0.418879	69	1.204277	114	1.989675	159	2.775074	204	3.560472
25	0.436332	70	1.221731	115	2.007129	160	2.792527	205	3.577925
26	0.453786	71	1.239184	116	2.024582	161	2.809980	206	3.595378
27	0.471239	72	1.256637	117	2.042035	162	2.827433	207	3.612832
28	0.488692	73	1.274090	118	2.059489	163	2.844887	208	3.630285
29	0.506145	74	1.291544	119	2.076942	164	2.862340	209	3.647738
30	0.523599	75	1.308997	120	2.094395	165	2.879793	210	3.665191
31	0.541052	76	1.326450	121	2.111848	166	2.897247	211	3.682645
32	0.558505	77	1.343904	122	2.129302	167	2.914700	212	3.700098
33	0.575959	78	1.361357	123	2.146755	168	2.932153	213	3.717551
34	0.593412	79	1.378810	124	2.164208	169	2.949606	214	3.735005
35	0.610865	80	1.396263	125	2.181662	170	2.967060	215	3.752458
36	0.628319	81	1.413717	126	2.199115	171	2.984513	216	3.769911
37	0.645772	82	1.431170	127	2.216568	172	3.001966	217	3.787364
38	0.663225	83	1.448623	128	2.234021	173	3.019420	218	3.804818
39	0.680678	84	1.466077	129	2.251475	174	3.036873	219	3.822271
40	0.698132	85	1.483530	130	2.268928	175	3.054326	220	3.839724
41	0.715585	86	1.500983	131	2.286381	176	3.071780	221	3.857178
42	0.733038	87	1.518436	132	2.303835	177	3.089233	222	3.874631
43	0.750492	88	1.535890	133	2.321288	178	3.106686	223	3.892084
44	0.767945	89	1.553343	134	2.338741	179	3.124139	224	3.909538
45	0.785398	90	1.570796	135	2.356195	180	3.141592	225	3.926991

LENGTH OF ARCHES FOR EVERY DEGREE. (*Continued.*)

226	3.944444	261	4.555309	296	5.166175	331	5.777040
227	3.961897	262	4.572763	297	5.183628	332	5.794493
228	3.979351	263	4.590216	298	5.201081	333	5.811946
229	3.996804	264	4.607669	299	5.218535	334	5.829400
230	4.014257	265	4.625123	300	5.235988	335	5.846853
231	4.031711	266	4.642576	301	5.253441	336	5.864306
232	4.049164	267	4.660029	302	5.270894	337	5.881760
233	4.066617	268	4.677482	303	5.288348	338	5.899213
234	4.084070	269	4.694936	304	5.305801	339	5.916666
235	4.101524	270	4.712389	305	5.323254	340	5.934120
236	4.118977	271	4.729842	306	5.340708	341	5.951573
237	4.136430	272	4.747296	307	5.358161	342	5.969026
238	4.153884	273	4.764749	308	5.375614	343	5.986479
239	4.171337	274	4.782202	309	5.393067	344	6.003933
240	4.188790	275	4.799655	310	5.410521	345	6.021386
241	4.206244	276	4.817109	311	5.427974	346	6.038839
242	4.223697	277	4.834562	312	5.445427	347	6.056293
243	4.241150	278	4.852015	313	5.462881	348	6.073746
244	4.258603	279	4.869469	314	5.480334	349	6.091200
245	4.276057	280	4.886922	315	5.497787	350	6.108652
246	4.293510	281	4.904375	316	5.515240	351	6.126106
247	4.310963	282	4.921829	317	5.532694	352	6.143559
248	4.328417	283	4.939282	318	5.550147	353	6.161012
249	4.345870	284	4.956735	319	5.567600	354	6.178466
250	4.363323	285	4.974188	320	5.585054	355	6.195919
251	4.380776	286	4.991642	321	5.602507	356	6.213372
252	4.398230	287	5.009095	322	5.619960	357	6.230825
253	4.415683	288	5.026548	323	5.637414	358	6.248279
254	4.433136	289	5.044002	324	5.654867	359	6.265732
255	4.450590	290	5.061455	325	5.672320	360	6.283185
256	4.468043	291	5.078908	326	5.689773		
257	4.485496	292	5.096361	327	5.707227		
258	4.502950	293	5.113815	328	5.724680		
259	4.520403	294	5.131268	329	5.742133		
260	4.537856	295	5.148721	330	5.759587		

## LENGTH OF ARCHES FOR EVERY MINUTE.

1	0.000291	16	0.004654	31	0.009018	46	0.013381
2	0.000582	17	0.004945	32	0.009308	47	0.013672
3	0.000873	18	0.005236	33	0.009599	48	0.013963
4	0.001164	19	0.005527	34	0.009890	49	0.014254
5	0.001454	20	0.005818	35	0.010181	50	0.014544
6	0.001745	21	0.006109	36	0.010472	51	0.014835
7	0.002036	22	0.006400	37	0.010763	52	0.015126
8	0.002327	23	0.006690	38	0.011054	53	0.015417
9	0.002618	24	0.006981	39	0.011345	54	0.015708
10	0.002909	25	0.007272	40	0.011636	55	0.015999
11	0.003200	26	0.007563	41	0.011926	56	0.016290
12	0.003491	27	0.007854	42	0.012217	57	0.016581
13	0.003782	28	0.008145	43	0.012508	58	0.016872
14	0.004072	29	0.008436	44	0.012799	59	0.017162
15	0.004363	30	0.008727	45	0.013090	60	0.017453



LENGTH OF ARCHES FOR EVERY SECOND.

1	0.000005	16	0.000078	31	0.000150	46	0.000223
2	0.000010	17	0.000082	32	0.000155	47	0.000228
3	0.000015	18	0.000087	33	0.000160	48	0.000233
4	0.000020	19	0.000092	34	0.000165	49	0.000238
5	0.000024	20	0.000097	35	0.000170	50	0.000242
6	0.000030	21	0.000102	36	0.000175	51	0.000247
7	0.000034	22	0.000107	37	0.000179	52	0.000252
8	0.000039	23	0.000112	38	0.000184	53	0.000257
9	0.000044	24	0.000116	39	0.000189	54	0.000262
10	0.000049	25	0.000121	40	0.000194	55	0.000267
11	0.000053	26	0.000126	41	0.000199	56	0.000272
12	0.000058	27	0.000131	42	0.000204	57	0.000276
13	0.000063	28	0.000136	43	0.000209	58	0.000281
14	0.000068	29	0.000141	44	0.000213	59	0.000286
15	0.000073	30	0.000145	45	0.000218	60	0.000291

*Mode of Application.*—When the angle,  $a$ , at the centre,  $M$ , of a part of a circle is known, then the radius must be multiplied with the sum of the figures attached to those degrees, minutes and seconds in the tables, and the length of the arch will be obtained.

For example, we want to know the length of an arch for  $97^\circ 53' 49''$ , when the radius of the circle is 12 feet. (Fig. 149<sup>b</sup>.)

For a radius as unit, the arch for  $97^\circ = 1.692969$   
 “ “ “ “  $53' = 0.015417$   
 “ “ “ “  $49'' = 0.000238$   
1.708624

This, multiplied by the radius, 12, gives 20.503488 feet, the length of the arch  $ABC$ , and when multiplied by the radius, 16, the length of arch = 27.337984.

Reversed, when the length of an arch = 98.765432 feet, and the radius of the circle = 20 feet, then for the angle at centre,  $M$ ,

$\frac{98.765432}{20} = 4.938272$

In the table where an arch =  $282^\circ = 4.921829$

Remainder, 0.016443

“ “ “ =  $56' = 0.016290$

Remainder, 0.000153

“ “ “ =  $31'' = 0.000150$

Balance, 0.000003

therefore the angle =  $282^\circ 56' 31''$ .

[Plates 22, 23 and 24—embracing Figs. 133 to 149.]

### C. PARABOLIC GIRDER OF 48 FEET, OR 16 METER, SPAN.

(*With Single Diagonal System.*)

Weight of girder = 500 kilograms per meter, or 1000 kilograms on each apex.

Plate 25,] Rolling load = 2500 kilograms per meter, or 5000  
Fig. 150.] kilograms on each apex. (Fig. 150.)

151.] The following skeleton (Fig. 151) shows the distribution of weight and load:

For the reactive force,  $D$ , of abutments, we have

$$D = 1000 \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \frac{7}{8} \right) + 5000 \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \frac{7}{8} \right);$$

152.] For the strain in  $x_1$  (Fig. 152) is

$$0 = x_1 \cdot \frac{7}{8} + D \cdot 2 \text{ (rot. } r. C);$$

and when the value of  $D$  is substituted,

$$0 = x_1 \cdot \frac{7}{8} + 1000 \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \frac{7}{8} \right) 2 + 5000 \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \frac{4}{8} + \frac{5}{8} + \frac{6}{8} + \frac{7}{8} \right) \cdot 2;$$

$$x_1 = -48000 \text{ kil.};$$

and for  $z_1$  from the same figure,

$$0 = -z_1 \cdot 0,8 + D \cdot 2 \text{ (rot. } r. B);$$

$$0 = -z_1 \cdot 0,8 + 1000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{7}{8} \right) \cdot 2 + 5000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{7}{8} \right) \cdot 2;$$

$$z_1 = +52500 \text{ kil.}$$

153.] For  $V$  we take as the point of rotation the intersection  $R$  of  $x_1$  and  $z_2$ , and it is

$$0 = -V_1 \cdot 2,8 - D \cdot 0,8; \quad (\text{Fig. 153.})$$

$$0 = -V_1 \cdot 2,8 - 1000 \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \dots + \frac{7}{8} \right) \cdot 0,8$$

$$- 5000 \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} + \dots + \frac{7}{8} \right) \cdot 0,8;$$

$$V_1 = -6000 \text{ kil.};$$

154.] For  $x_2$  (rot.  $r. E$ , Fig. 154) is

$$0 = x_2 \cdot 1,5 + D \cdot 4 - 1000 \times 2 - 5000 \times 2,$$

$$\text{or } 0 = x_2 \cdot 1,5 + 1000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{7}{8} \right) \cdot 4 + 5000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{7}{8} \right) \cdot 4 - 1000 \times 2 - 5000 \times 2;$$

and now, according to the rule formerly given,

$$\begin{aligned} 0 &= x_2 \cdot 1,5 + 1000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{6}{8} \right) \cdot 4 + \left( \frac{7}{8} \times 4 - 2 \right) \right]; \\ &+ 5000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{6}{8} \right) \cdot 4 + \left( \frac{7}{8} \times 4 - 2 \right) \right]; \\ x_2 &= -48000 \text{ kil.} \end{aligned}$$

154.] For  $y_2$  (rot.  $r. R$ , Fig. 154) is

$$\begin{aligned} 0 &= y_2 \cdot 1,68 - 1000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{7}{8} \right) \cdot 0,8 - 5000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{7}{8} \right) \cdot 0,8 + 1000 \times 2,8 + 5000 \times 2,8; \\ 0 &= y_2 \cdot 1,68 - 1000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{6}{8} \right) \cdot 0,8 - (2,8 - \frac{7}{8} \times 0,8) \right] \\ &- 5000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{6}{8} \right) \cdot 0,8 + 5000 (2,8 - \frac{7}{8} \times 0,8); \end{aligned}$$

and omitting from the movable load at one time the members with the symbol  $+$ , and at another time with the symbol  $-$ ,

$$\begin{aligned} 0 &= y_2 \cdot 1,68 - 1000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{6}{8} \right) \cdot 0,8 - (2,8 - \frac{7}{8} \times 0,8) \right] \\ &- 5000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{6}{8} \right) \cdot 0,8, \end{aligned}$$

$$\text{or } y_2 = +6250 \text{ kil.},$$

$$\text{and } 0 = y_2 \cdot 1,68 - 1000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{6}{8} \right) \cdot 0,8 - (2,8 - \frac{7}{8} \times 0,8) \right] + 5000 (2,8 - \frac{7}{8} \times 0,8);$$

$$y_2 = -6250 \text{ kil.}$$

In omitting no member of the first equation,  $y_2$  will  $= 0$ , as per example for a full load. (See remarks on Parabolic Girders and the Arched Truss.)

For  $z_2$  (rot.  $r. B$ ) and the members in the prescribed form directly arranged, will be from Fig. 154.

$$\begin{aligned} 0 &= z_2 \cdot 0,835 + 1000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{7}{8} \right) 2 + 5000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{7}{8} \right) 2; \\ z_2 &= +50300 \text{ kil.} \end{aligned}$$

155.] For  $V_2$  (rot.  $r. S$ ) we find from Fig. 155,

$$\begin{aligned} 0 &= -V_2 \cdot 8 - 1000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{6}{8} \right) \cdot 4 - (6 - \frac{7}{8} \times 4) \right] \\ &- 5000 \left( \frac{1}{8} + \frac{2}{8} + \dots + \frac{6}{8} \right) + 5000 (6 - \frac{7}{8} \times 4); \end{aligned}$$

F

$$0 = -V_2 \cdot 8 - 1000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots \frac{6}{8} \right) \cdot 4 - (6 - \frac{7}{8} \times 4) \right] - 5000 \left( \frac{1}{8} + \frac{2}{8} + \dots \frac{6}{8} \right) \cdot 4;$$

$$V_2 = -7560 \text{ kil.},$$

$$\text{and } 0 = -V_2 \cdot 8 - 1000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots \frac{6}{8} \right) \cdot 4 - (6 - \frac{7}{8} \times 4) \right] + 5000 (6 - \frac{7}{8} \times 4);$$

$$V_2 = +560 \text{ kil.}$$

In the same way we find for the remaining,

$$0 = x_3 \cdot 1,875 + 1000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots \frac{5}{8} \right) \cdot 6 + \left( \frac{6}{8} \times 6 - 2 \right) + \left( \frac{7}{8} \times 6 - 4 \right) \right]$$

$$+ 5000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots \frac{5}{8} \right) \cdot 6 + \left( \frac{6}{8} \times 6 - 2 \right) + \left( \frac{7}{8} \times 6 - 4 \right) \right];$$

$$x_3 = -48000 \text{ kil.};$$

$$0 = y_3 \cdot 5,47 - 1000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \dots \frac{5}{8} \right) \cdot 4 - (8 - \frac{6}{8} \times 4) - (6 - \frac{7}{8} \times 4) \right]$$

$$- 5000 \left( \frac{1}{8} + \frac{2}{8} + \dots \frac{5}{8} \right) \cdot 4 + 5000 (8 - \frac{6}{8} \times 4) + 5000 (6 - \frac{7}{8} \times 4);$$

$$y_3 = +6850 \text{ kil.},$$

$$\text{and } y_3 = -6850 \text{ "}$$

$$0 = -z_3 \cdot 1,474 + 1000 \left[ \left( \frac{1}{8} + \dots \frac{6}{8} \right) \cdot 4 + \left( \frac{7}{8} \times 4 - 2 \right) \right]$$

$$+ 5000 \left[ \left( \frac{1}{8} + \dots \frac{6}{8} \right) \cdot 4 + \left( \frac{7}{8} \times 4 - 2 \right) \right];$$

$$z_3 = +48900 \text{ kil};$$

$$0 = -V_3 \cdot 30 - 1000 \left[ \left( \frac{1}{8} + \dots \frac{5}{8} \right) \cdot 24 - (28 - \frac{6}{8} \times 24) - (26 - \frac{7}{8} \times 24) \right]$$

$$- 5000 \left( \frac{1}{8} + \dots \frac{5}{8} \right) \cdot 24 + 5000 (28 - \frac{6}{8} \times 24) + 5000 (26 - \frac{7}{8} \times 24);$$

$$V_3 = +1500 \text{ kil.},$$

$$\text{and } V_3 = -8500 \text{ "}$$

$$0 = x_4 \cdot 2 + 1000 \left[ \left( \frac{1}{8} + \dots \frac{4}{8} \right) \cdot 8 + \left( \frac{5}{8} \times 8 - 2 \right) + \left( \frac{6}{8} \times 8 - 4 \right) + \left( \frac{7}{8} \times 8 - 6 \right) \right]$$

$$+ 5000 \left[ \left( \frac{1}{8} + \dots \frac{4}{8} \right) \cdot 8 + \left( \frac{5}{8} \times 8 - 2 \right) + \frac{6}{8} \times 8 - 4 + \left( \frac{7}{8} \times 8 - 6 \right) \right];$$

$$y_4 = -48000 \text{ kil.};$$

$$0 = y_4 \cdot 21,2 - 1000 \left[ \left( \frac{1}{8} + \dots \frac{4}{8} \right) \cdot 24 - (30 - \frac{5}{8} \times 24) - (28 - \frac{6}{8} \times 24) - (26 - \frac{7}{8} \times 24) \right]$$

$$- 5000 \left( \frac{1}{8} + \dots \frac{4}{8} \right) .24 + 5000 \left[ (30 - \frac{5}{8} \times 24) + (28 - \frac{6}{8} \times 24) + (26 - \frac{7}{8} \times 24) \right];$$

$$y_4 = + 7080 \text{ kil.},$$

$$\text{and } y_4 = - 7080 \text{ "}$$

$$0 = - z_4 . 1,873 + 1000 \left[ \left( \frac{1}{8} + \dots \frac{5}{8} \right) . 6 + \left( \frac{6}{8} \times 6 - 2 \right) + \left( \frac{7}{8} \times 6 - 4 \right) \right]$$

$$+ 5000 \left[ \left( \frac{1}{8} + \dots \frac{5}{8} \right) . 6 + \left( \frac{6}{8} \times 6 - 2 \right) + \left( \frac{7}{8} \times 6 - 4 \right) \right];$$

$$z_4 = + 48100 \text{ kil.}$$

The equations now following are for the section of figure regarded to the right of the cut *st*.

$$0 = - V_4 . 32 + 1000 \left[ \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} \right) 24 - (32 - \frac{4}{8} \times 24) - (30 - \frac{5}{8} \times 24) - (28 - \frac{6}{8} \times 24) - (26 - \frac{7}{8} \times 24) \right]$$

$$+ 5000 \left( \frac{1}{8} + \frac{2}{8} + \frac{3}{8} \right) 24 - 5000 \left[ (32 - \frac{4}{8} \times 24) + (30 - \frac{5}{8} \times 24) + (28 - \frac{6}{8} \times 24) + (26 - \frac{7}{8} \times 24) \right];$$

$$V_4 = + 1800 \text{ kil.},$$

$$\text{and } V_4 = - 8800 \text{ "}$$

$$0 = - x_5 . 1,875 - 1000 \left[ \left( \frac{1}{8} + \dots \frac{5}{8} \right) 6 + \left( \frac{6}{8} \times 6 - 2 \right) + \left( \frac{7}{8} \times 6 - 4 \right) \right]$$

$$- 5000 \left[ \left( \frac{1}{8} + \dots \frac{5}{8} \right) 6 + \left( \frac{6}{8} \times 6 - 2 \right) + \left( \frac{7}{8} \times 6 - 4 \right) \right];$$

$$x_5 = - 48000 \text{ kil.};$$

$$0 = y_5 . 21,88 + 1000 \left[ \left( \frac{1}{8} + \dots \frac{4}{8} \right) 24 - (30 - \frac{5}{8} \times 24) - (28 - \frac{6}{8} \times 24) - (26 - \frac{7}{8} \times 24) \right]$$

$$+ 5000 \left( \frac{1}{8} + \dots \frac{4}{8} \right) 24 - 5000 \left[ (30 - \frac{5}{8} \times 24) + (28 - \frac{6}{8} \times 24) + (26 - \frac{7}{8} \times 24) \right];$$

$$y_5 = + 6850 \text{ kil.},$$

$$\text{and } y_5 = - 6850 \text{ "}$$

$$0 = z_5 . 1,996 - 1000 \left[ \left( \frac{1}{8} + \dots \frac{4}{8} \right) 8 + \left( \frac{5}{8} \times 8 - 2 \right) + \left( \frac{6}{8} \times 8 - 4 \right) + \left( \frac{7}{8} \times 8 - 6 \right) \right]$$

$$- 5000 \left[ \left( \frac{1}{8} + \dots \frac{4}{8} \right) 8 + \left( \frac{5}{8} \times 8 - 2 \right) + \left( \frac{6}{8} \times 8 - 4 \right) + \left( \frac{7}{8} \times 8 - 6 \right) \right];$$

$$z_5 = + 48100 \text{ kil.};$$

$$0 = -V_5 \cdot 10 + 1000 \left[ \left( \frac{1}{8} + \dots \frac{4}{8} \right) 4 - \left( 10 - \frac{5}{8} \times 4 \right) - \left( 8 - \frac{6}{8} \times 4 \right) - \left( 6 - \frac{7}{8} \times 4 \right) \right]$$

$$+ 5000 \left[ \left( \frac{1}{8} + \dots \frac{4}{8} \right) 4 - 5000 \left[ \left( 10 - \frac{5}{8} \times 4 \right) + \left( 8 - \frac{6}{8} \times 4 \right) + \left( 6 - \frac{7}{8} \times 4 \right) \right] \right];$$

$$V_5 = +1500 \text{ kil.},$$

and

$$V_5 = -8500 \text{ "}$$

$$0 = -x_6 \cdot 1,5 - 1000 \left[ \left( \frac{1}{8} + \dots \frac{6}{8} \right) \cdot 4 + \left( \frac{7}{8} \times 4 - 2 \right) \right] - 5000 \left[ \left( \frac{1}{8} + \dots \frac{6}{8} \right) 4 + \left( \frac{7}{8} \times 4 - 2 \right) \right];$$

$$x_6 = -48000 \text{ kil.};$$

$$0 = y_6 \cdot 6 + 1000 \left[ \left( \frac{1}{8} + \dots \frac{5}{8} \right) 4 - \left( 8 - \frac{6}{8} \times 4 \right) - \left( 6 - \frac{7}{8} \times 4 \right) \right] + 5000 \left( \frac{1}{8} + \dots \frac{5}{8} \right) 4 - 5000 \left[ \left( 8 - \frac{6}{8} \times 4 \right) + \left( 6 - \frac{7}{8} \times 4 \right) \right];$$

$$y_6 = +6250 \text{ kil.},$$

and

$$y_6 = -6250 \text{ "}$$

$$0 = z_6 \cdot 1,84 - 1000 \left[ \left( \frac{1}{8} + \dots \frac{5}{8} \right) 6 + \left( \frac{6}{8} \times 6 - 2 \right) + \left( \frac{7}{8} \times 6 - 4 \right) \right] - 5000 \left[ \left( \frac{1}{8} + \dots \frac{5}{8} \right) 6 + \left( \frac{6}{8} \times 6 - 2 \right) + \left( \frac{7}{8} \times 6 - 4 \right) \right];$$

$$z_6 = +48900 \text{ kil.};$$

$$0 = -V_6 \cdot 4,8 + 1000 \left[ \left( \frac{1}{8} + \dots \frac{5}{8} \right) 0,8 - \left( 4,8 - \frac{6}{8} \times 0,8 \right) - \left( 2,8 - \frac{7}{8} \times 0,8 \right) \right]$$

$$+ 5000 \left( \frac{1}{8} + \dots \frac{5}{8} \right) 0,8 - 5000 \left[ \left( 4,8 - \frac{6}{8} \times 0,8 \right) + \left( 2,8 - \frac{7}{8} \times 0,8 \right) \right];$$

$$V_6 = +560 \text{ kil.},$$

and

$$V_6 = -7560 \text{ "}$$

$$0 = -x_7 \cdot 0,875 - 1000 \left( \frac{1}{8} + \dots \frac{7}{8} \right) 2 - 5000 \left( \frac{1}{8} + \dots \frac{7}{8} \right) 2;$$

$$x_7 = -48000 \text{ kil.};$$

$$0 = y_7 \cdot 1,92 + 1000 \left[ \left( \frac{1}{8} + \dots \frac{6}{8} \right) 0,8 - \left( 2,8 - \frac{7}{8} \times 0,8 \right) \right] + 5000 \left( \frac{1}{8} + \dots \frac{6}{8} \right) 0,8 - 5000 \left( 2,8 - \frac{7}{8} \times 0,8 \right);$$

$$y_7 = +5470 \text{ kil.},$$

and

$$y_7 = -5470 \text{ "}$$

$$0 = z_7 \cdot 1,43 - 1000 \left[ \left( \frac{1}{8} + \dots \frac{6}{8} \right) 4 + \left( \frac{7}{8} \cdot 4 - 2 \right) \right] - 5000 \left[ \left( \frac{1}{8} + \dots \frac{6}{8} \right) 4 + \left( \frac{7}{8} \times 4 - 2 \right) \right];$$

$$z_7 = +50300 \text{ kil.};$$







$$0 = -V_7 \cdot 2 - 1000 \cdot 2 - 5000 \cdot 2;$$

$$V_7 = -6000 \text{ kil.};$$

$$0 = -x_8 \cdot 0,875 - 1000 \left(\frac{1}{8} + \dots \frac{7}{8}\right) 2 - 5000 \frac{1}{8} + \dots \frac{7}{8} 2;$$

$$x_8 = -48000 \text{ kil.};$$

$$0 = z_8 \cdot 0,8 - 1000 \left(\frac{1}{8} + \dots \frac{7}{8}\right) 2 - 5000 \left(\frac{1}{8} + \dots \frac{7}{8}\right) 2;$$

$$z_8 = +52500 \text{ kil.}$$

156.] In the skeleton (Fig. 156) will be found the combined results.

Comparing the equations with the skeleton, we find the most strain in a certain diagonal, say  $y_3$ , in the third panel, when all the apexes to the right are loaded, and the most compression when all the apexes to the left are loaded. (Fig. 157.)

158.] In the same panel, when the diagonal is reversed or replaced by  $y_6$ , the strain will be like  $y_6$ . (Fig. 158.)

When both diagonals,  $y_3$  and  $y_6$ , in panel 3, are existing and constructed like tie-rods, then each one separately will only be strained by a load producing tension. Meanwhile the other is inactive, and in this case only the positive strains of  $y$  come into consideration. So for  $y_3$  and  $y_6$  in panel 3 (Fig. 159),

159.] and in the same manner with the other diagonals, as in Plate 26, the skeleton. (Fig. 160.)

For the verticals only the greatest negative (—) strains come into consideration. Because the diagonals have tensile strain, there can be compression only in the verticals.

In a construction with vertical tie-rods and diagonal braces, for the braces only the greatest negative (—) strains, and for the verticals the positive (+) strains, come into consideration. The only compression in the verticals results from the direct load, varying between 1000 kil. and  $1000 + 5000$  kil., and is, therefore, the maximum compression in the verticals,

$$V = -6000 \text{ kil.}$$

In this case the inability of diagonals for tensile strain is to be represented by double lines. Also for a girder with single diagonal, but symmetrical system, the compression of the vertical at the centre will be only  $-6000$ ; the other strains all resulting from the first calculation.

161,  
162,  
163.]

Here may follow a combination of different cases in Figs. 161, 162 and 163.

When in the first skeleton (Fig. 156) the symbols + and — are reversed, it represents the strains for a parabolic girder, with the horizontal flange on below; and the variations of this case can be made in the same manner as before. (See Figs. 164 to 168.)

*Remark.*—Two peculiarities we observe by the calculation of parabolic girders. First, the strength in the horizontal chords or flanges is the largest with a full load, and is the same all over. Second, the strain in each diagonal is with a full load = 0.

This last fact presents itself from the first theorem, for  $x = x_1$  in 169.] Fig. 169 is only possible when  $y = 0$ , otherwise the horizontal component of  $y$  would enlarge or diminish  $x$  or  $x_1$ , and this will be true also in case the width of panels should be different, when only the apexes are in a parabolic curve. This shows the necessity for the application of the rule to calculate the maximum and minimum strain as prescribed in the example.

[Plates 25 and 26—embracing Figs. 150 to 169.]

## D. THE ARCHED TRUSS.

Plate 27,] The following calculations are for the roof of the Fig. 170.] Central Depot at Birmingham:

Girder, 208 feet in length. (Fig. 170.)

13 panels, each 16 feet in horizontal length, and 24 feet in depth.

The distances of top intersections to the distances of bottom intersections from the horizontal line are as 40 to 16, or =  $2\frac{1}{2}$  to 1.

The distance of main rafters = 24 feet; weight and pressure of snow and wind = 40 lbs. per square foot of horizontal projection.

$$208 \times 24 \times 40 = 199680 \text{ lbs. (the weight of load),}$$

or for each panel = ,

$$\frac{199680}{13} = 15360 \text{ lbs., or 7,5 tons.}$$

The weight of structure = 1,5 tons for each panel.

The pressure,  $D$ , on the abutment, will be

$$D = (1,5 + 7,5) \left( \frac{1}{13} + \frac{2}{13} + \frac{3}{13} + \dots + \frac{11}{13} + \frac{12}{13} \right) = 9 \times \frac{78}{13} = 54 \text{ tons.}$$

171.] Therefore, per example for  $x_4$ , in Fig. 171, when the length of 16 feet is taken as unit, or = 1,

$$0 = x_4 \cdot 1,205 + 54 \times 4 - (7,5 + 1,5) (1 + 2 + 3) \text{ (rot. round } M \text{):}$$

$$x_4 = -134,4 \text{ tons;}$$

and for  $z_4$ ,

$$0 = -z_4 \cdot 1,055 + 54 \times 3 - (7,5 + 1,5) (1 + 2) \text{ (rot. r. } N \text{);}$$

$$z_4 = +128,0 \text{ tons.}$$

In the same manner,

$$0 = x_1 \cdot 0,347 + 54 \times 1, \quad \text{or } x_1 = -155,6 \text{ t.}$$

$$0 = -z_1 \cdot 0,41 + 54 \times 1, \quad \text{or } z_1 = +131,7 \text{ t.}$$

$$0 = x_2 \cdot 0,672 + 54 \times 2 - 9 \times 1, \quad \text{or } x_2 = -147,3 \text{ t.}$$

$$0 = -z_2 \cdot 0,415 + 54 \times 1, \quad \text{or } z_2 = +130,2 \text{ t.}$$

$$0 = x_3 \cdot 0,963 + 54 \times 3 - 9 \cdot (1 + 2) \quad \text{or } x_3 = -140,2 \text{ t.}$$

$$0 = -z_3 \cdot 0,767 + 54 \times 2 - 9 \times 1, \quad \text{or } z_3 = +129,1 \text{ t.}$$

$$0 = x_5 \cdot 1,382 + 54 \times 5 - 9(1 + 2 + 3 + 4), \quad \text{or } x_5 = -130,2 \text{ t.}$$

$$0 = -z_5 \cdot 1,272 + 54 \times 4 - 9(1 + 2 + 3) \quad \text{or } z_5 = +127,3 \text{ t.}$$

$$0 = x_6 \cdot 1,481 + 54 \times 6 - 9(1 + 2 + 3 + 4 + 5), \quad \text{or } x_6 = -127,6 \text{ t.}$$

$$0 = -z_6 \cdot 1,419 + 54 \times 5 - 9(1 + 2 + 3 + 4), \quad \text{or } z_6 = +126,9 \text{ t.}$$

$$0 = x_7 \cdot 1,491 + 54 \times 7 - 9(1 + 2 + 3 + 4 + 5 + 6), \quad \text{or } x_7 = -126,7 \text{ t.}$$

$$0 = -z_7 \cdot 1,491 + 54 \times 6 - 9(1 + 2 + 3 + 4 + 5), \quad \text{or } z_7 = +126,7 \text{ t.}$$

$$0 = x_8 \cdot 1,41 + 54 \times 8 - 9(1 + 2 + \dots 7), \quad \text{or } x_8 = -127,6 \text{ t.}$$

$$0 = -z_8 \cdot 1,489 + 54 \times 7 - 9(1 + 2 + \dots 6), \quad \text{or } z_8 = +126,9 \text{ t.}$$

$$0 = x_9 \cdot 1,244 + 54 \times 9 - 9(1 + 2 + \dots 8), \quad \text{or } x_9 = -130,2 \text{ t.}$$

$$0 = -z_9 \cdot 1,414 + 54 \times 8 - 9(1 + 2 + \dots 7), \quad \text{or } z_9 = +127,3 \text{ t.}$$

$$0 = x_{10} \cdot 1,004 + 54 \times 10 - 9(1 + 2 + \dots 9), \text{ or } x_{10} = -134,4 \text{ t.}$$

$$0 = -z_{10} \cdot 1,265 + 54 \times 9 - 9(1 + 2 + \dots 8), \text{ or } z_{10} = +128,0 \text{ t.}$$

$$0 = x_{11} \cdot 0,706 + 54 \times 11 - 9(1 + 2 + \dots 10), \text{ or } x_{11} = -140,2 \text{ t.}$$

$$0 = -z_{11} \cdot 1,046 + 54 \times 10 - 9(1 + 2 + \dots 9), \text{ or } z_{11} = +129,1 \text{ t.}$$

$$0 = x_{12} \cdot 0,367 + 54 \times 12 - 9(1 + 2 + \dots 11), \text{ or } x_{12} = -147,3 \text{ t.}$$

$$0 = -z_{12} \cdot 0,76 + 54 \times 11 - 9(1 + 2 + \dots 10), \text{ or } z_{12} = +130,2 \text{ t.}$$

$$0 = x_{13} \cdot 0,347 + 54 \times 12 - 9(1 + 2 + \dots 11), \text{ or } x_{13} = -155,6 \text{ t.}$$

$$0 = -z_{13} \cdot 0,41 + 54 \times 12 - 9(1 + 2 + \dots 11), \text{ or } z_{13} = +131,7 \text{ t.}$$

*Remark.*—The results noted in Fig. 176 show that the greatest strains in the symmetrical sections of flanges are the same, though the diagonals of one-half of the girder are reversed to the others, and it follows that for the definition of strain in flanges it will be the same if we take the point for rotation in the right or left apex.

This is only possible when the strain in the diagonal = 0, and therefore shows us that by a full load, as in parabolic girders, no strain in diagonals exists. Nevertheless, a partial load (from snow or wind or removing of sheeting) being unavoidable, the diagonal connections are a necessity.

#### CALCULATION OF STRAIN $y$ IN THE DIAGONALS.

172.] For  $y_4$  (see Fig. 172), when the point of rotation,  $O$ , in the intersection of  $x_4$  and  $z_4$  and the length  $OA$ , found by construction = 32 feet, or, for easier calculation, 16 feet = unit (1); therefore  $OA = 2$ , and the lever for  $y_4 = PO = 4,68$ .

$$0 = y_4 \cdot 4,68 - D \cdot 2 + 1,5 [(3 + 2) + (2 + 2) + (1 + 2)] + 7,5 [(3 + 2) + (2 + 2) + (1 + 2)],$$

$$\text{and } D = 1,5 \left( \frac{1}{1^3} + \frac{2}{1^3} + \dots \frac{12}{1^3} \right) + 7,5 \left( \frac{1}{1^3} + \frac{2}{1^3} + \dots \frac{12}{1^3} \right),$$

substituted with its members of permanent and variable load on their respective places,

$$0 = y_4 \cdot 4,68 - 1,5 \left[ \left( \frac{1}{1^3} + \frac{2}{1^3} + \dots \frac{9}{1^3} \right) 2 - (3 + 2 + 1) \left( 1 + \frac{2}{1^3} \right) \right] - 7,5 \left[ \frac{1}{1^3} + \frac{2}{1^3} + \dots \frac{9}{1^3} \right] + 7,5 (3 + 2 + 1) \left( 1 + \frac{2}{1^3} \right).$$

The solution of this equation shows the member for a permanent load = 0, and therefore our equation in its more simple form—

$$0 = -y_4 \cdot 4,68 - 7,5 \left( \frac{1}{13} + \frac{2}{13} + \dots + \frac{9}{13} \right) 2 + 7,5 (3 + 2 + 1) \left( 1 + \frac{2}{13} \right),$$

or, according to the rule formerly given,

$$\text{I. } 0 = -y_4 \cdot 4,68 - 7,5 \left( \frac{1}{13} + \frac{2}{13} + \dots + \frac{9}{13} \right) 2;$$

$$\text{II. } 0 = -y_4 \cdot 4,68 + 7,5 (3 + 2 + 1) \left( 1 + \frac{2}{13} \right),$$

$$\text{or } y_4 = +11,1 \text{ tons, and } y_4 = -11,1 \text{ tons.}$$

In the same way for the other diagonals and the length of lever from construction,

$$0 = y_2 \cdot 0,92 - 7,5 \left( \frac{1}{13} + \frac{2}{13} + \dots + \frac{11}{13} \right) \cdot 0,2 + 7,5 \left( 1 + \frac{9}{13} \right);$$

$$y_2 = +8,3, \quad \text{and } y_2 = -8,3 \text{ tons};$$

$$0 = y_3 \cdot 2,52 - 7,5 \left( \frac{1}{13} + \dots + \frac{10}{13} \right) 0,75 + 7,5 (2 + 1) \left( 1 + \frac{9 \cdot 7,5}{13} \right);$$

$$y_3 = +9,5, \quad \text{and } y_3 = -9,5 \text{ tons};$$

$$0 = y_5 \cdot 8,3 - 7,5 \left( \frac{1}{13} + \dots + \frac{8}{13} \right) 5 + 7,5 (4 + 3 + 2 + 1) \left( 1 + \frac{5}{13} \right);$$

$$y_5 = +12,6, \quad \text{and } y_5 = -12,6 \text{ tons};$$

$$0 = y_6 \cdot 17,6 - 7,5 \left( \frac{1}{13} + \dots + \frac{7}{13} \right) 15 + 7,5 (5 + 4 + 3 + 2 + 1) \left( 1 + \frac{5}{13} \right);$$

$$y_6 = +13,8, \quad \text{and } y_6 = -13,8 \text{ tons.}$$

The point of rotation,  $O$ , is for the diagonal of the middle panel in infinite distance. (See girders with horizontal top and bottom flanges.)

The sinus of the angle formed by  $y_7$  and a horizontal line = 0,831, leading to the equation in its most simple form (as before explained in examples for girders with horizontal top and bottom flanges).

$$0 = y_7 \cdot 0,831 - 7,5 \left( \frac{1}{13} + \dots + \frac{6}{13} \right) + 7,5 (6 + \dots + 1) \frac{1}{13};$$

$$y_7 = +14,6, \quad \text{and } y_7 = -14,6 \text{ tons.}$$

For the equations now following, the point of rotation will be on the opposite side; therefore the symbols of moments are reversed.

$$0 = -y_8 \cdot 16,1 + 7,5 \left( \frac{1}{13} + \dots + \frac{5}{13} \right) 28 - 7,5 (7 + \dots + 1) \left( \frac{28}{13} - 1 \right);$$

$$y_8 = +15,0, \quad \text{and } y_8 = -15,0 \text{ tons};$$

$$0 = -y_9 \cdot 7,1 + 7,5 \left( \frac{1}{13} + \dots + \frac{4}{13} \right) 18 - 7,5 (8 + \dots + 1) \left( \frac{18}{13} - 1 \right);$$

$$y_9 = +14,6, \quad \text{and } y_9 = -14,6 \text{ tons};$$

$$0 = -y_{10} \cdot 3,68 + 7,5 \left( \frac{1}{13} + \frac{2}{13} + \frac{3}{13} \right) 15 - 7,5 (9 + \dots 1) \left( \frac{15}{2} - 1 \right);$$

$$y_{10} = +14,1, \quad \text{and } y_{10} = -14,1 \text{ tons};$$

$$0 = -y_{11} \cdot 1,82 + 7,5 \left( \frac{1}{13} + \frac{2}{13} \right) \cdot 13,75 - 7,5 (10 + \dots 1) \left( \frac{13,75}{2} - 1 \right);$$

$$y_{11} = +13,0, \quad \text{and } y_{11} = -13,0 \text{ tons};$$

$$0 = -y_{12} \cdot 0,65 + 7,5 \times \frac{1}{13} \times 13,2 - 7,5 (11 + \dots 1) \left( \frac{13,2}{2} - 1 \right);$$

$$y_{12} = +11,6, \quad \text{and } y_{12} = -11,6 \text{ tons.}$$

#### CALCULATION OF STRAIN IN THE VERTICALS $V$ .

173.] For  $V_1$ , when the point of rotation in the intersection of  $x_1$  and  $z_1$ , which by construction  $= 0,1$  to the right of  $A$  (Fig. 173),

$$0 = -V_1 \cdot 0,9 + D \cdot 0,1,$$

$$\text{or } 0 = -V_1 \cdot 0,9 + 1,5 \left( \frac{1}{13} + \frac{2}{13} + \dots \frac{12}{13} \right) 0,1 + 7,5 \left( \frac{1}{13} + \frac{2}{13} + \dots \frac{12}{13} \right) 0,1;$$

$$V_1 = +6 \text{ tons.}$$

174.] For  $V_2$ , the point of rotation in the intersection of  $x_2$  and  $z_2 = 0,06$  to the right of  $A$ . (Fig. 174.)

$$0 = -V_2 \cdot 1,94 + D \cdot 0,06 + 1,5 \times 0,94 + 7,5 \times 0,94;$$

$$0 = -V_2 \cdot 1,94 + 1,5 \left[ \left( \frac{1}{13} + \dots \frac{11}{13} \right) 0,06 + \left( 1 - \frac{0,06}{13} \right) \right]$$

$$+ 7,5 \left( \frac{1}{13} + \dots \frac{11}{13} \right) 0,06 + 7,5 \left( 1 - \frac{0,06}{13} \right);$$

$$V_2 = +6 \text{ tons.}$$

175.] For the equations now following, the point of rotation,  $O$ , will appear to the left of  $A = 0,214$  for the intersection of  $x_3$  and  $z_3$ , and for  $V_3$  (Fig. 175) we have

$$0 = -V_3 \cdot 3,214 - 1,5 \left[ \left( \frac{1}{13} + \dots \frac{10}{13} \right) 0,214 - (2+1) \left( 1 + \frac{0,214}{13} \right) \right] \\ - 7,5 \left( \frac{1}{13} + \dots \frac{10}{13} \right) 0,214 + 7,5 (2+1) \left( 1 + \frac{0,214}{13} \right);$$

and omitting at one time the positive and at another time the negative members of the movable load, we find

$$V_3 (\text{max.}) = +8,1 \text{ tons}$$

$$V_3 (\text{min.}) = -1,1 \text{ "}$$

and  $V_3 = +6$  tons when no member is omitted, which will be the

same for the other verticals, or  $V_4 = V_5 = V_6 \dots = 6$  tons; *i. e.*, for a full load of the truss.

In the same way

$$0 = -V_4 \cdot 4,91 - 1,5 \left[ \left( \frac{1}{18} + \dots \frac{9}{18} \right) 0,91 - (3 + 2 + 1) \left( 1 + \frac{0,91}{18} \right) \right] \\ - 7,5 \left( \frac{1}{18} + \dots \frac{9}{18} \right) 0,91 + 7,5 (3 + 2 + 1) \left( 1 + \frac{0,91}{18} \right);$$

$$V_4 (\text{max.}) = +10,8;$$

$$V_4 (\text{min.}) = -3,8;$$

$$0 = -V_5 \cdot 7,5 - 1,5 \left[ \left( \frac{1}{18} + \dots \frac{8}{18} \right) 2,5 - (4 + \dots 1) \left( 1 + \frac{2,5}{18} \right) \right] \\ - 7,5 \left( \frac{1}{18} + \dots \frac{8}{18} \right) 2,5 + 7,5 (4 + \dots 1) \left( 1 + \frac{2,5}{18} \right);$$

$$V_5 = +12,9;$$

$$V_5 = -5,9;$$

$$0 = -V_6 \cdot 12,6 - 1,5 \left[ \left( \frac{1}{18} + \dots \frac{7}{18} \right) 6,6 - (5 + \dots 1) \left( 1 + \frac{6,6}{18} \right) \right] \\ - 7,5 \left( \frac{1}{18} + \dots \frac{7}{18} \right) 6,6 + 7,5 (5 + \dots 1) \left( 1 + \frac{6,6}{18} \right);$$

$$V_6 = +14,5;$$

$$V_6 = -7,5;$$

$$0 = -V_7 \cdot 31,5 - 1,5 \left[ \left( \frac{1}{18} + \dots \frac{6}{18} \right) 24,5 - (6 + \dots 1) \left( 1 + \frac{24,5}{18} \right) \right] \\ - 7,5 \left( \frac{1}{18} + \dots \frac{6}{18} \right) 24,5 + 7,5 (6 + \dots 1) \left( 1 + \frac{24,5}{18} \right);$$

$$V_7 = +15,4;$$

$$V_7 = -8,4.$$

In the equations now following, the point of rotation on the opposite side gives,

$$0 = V_8 \cdot 60 + 1,5 \left[ \left( \frac{1}{18} + \dots \frac{5}{18} \right) 68 - (7 + \dots 1) \left( \frac{68}{18} - 1 \right) \right] \\ + 7,5 \left( \frac{1}{18} + \dots \frac{5}{18} \right) 68 - 7,5 (7 + \dots 1) \left( \frac{68}{18} - 1 \right);$$

$$V_8 = +15,8;$$

$$V_8 = -8,8;$$

$$0 = V_9 \cdot 13,5 + 1,5 \left[ \left( \frac{1}{18} + \dots \frac{4}{18} \right) 22,5 - (8 + \dots 1) \left( \frac{22,5}{18} - 1 \right) \right] \\ + 7,5 \left( \frac{1}{18} + \dots \frac{4}{18} \right) 22,5 - 7,5 (8 + \dots 1) \left( \frac{22,5}{18} - 1 \right);$$

$$V_9 = +15,6;$$

$$V_9 = -8,6;$$

$$0 = V_{10} \cdot 6,43 + 1,5 \left[ \left( \frac{1}{13} + \frac{2}{13} + \frac{3}{13} \right) 16,43 - (9 + 1) \left( \frac{16,43}{13} - 1 \right) \right] \\ + 7,5 \left( \frac{1}{13} + \frac{2}{13} + \frac{3}{13} \right) 16,43 - 7,5 (9 + \dots 1) \left( \frac{16,43}{13} - 1 \right);$$

$$V_{10} = + 14,8;$$

$$V_{10} = - 7,8;$$

$$0 = V_{11} \cdot 3,3 + 1,5 \left[ \left( \frac{1}{13} + \frac{2}{13} \right) 14,3 - (10 + \dots 1) \left( \frac{14,3}{13} - 1 \right) \right] \\ + 7,5 \left( \frac{1}{13} + \frac{2}{13} \right) 14,3 - 7,5 (10 + \dots 1) \left( \frac{14,3}{13} - 1 \right);$$

$$V_{11} = + 13,5;$$

$$V_{11} = - 6,5;$$

$$0 = V_{12} \cdot 1,385 + 1,5 \left[ \frac{1}{13} \times 13,385 - (11 + \dots 1) \left( \frac{13,385}{13} - 1 \right) \right] \\ + 7,5 \times \frac{1}{13} \times 13,385 - 7,5 (11 + \dots 1) \left( \frac{13,385}{13} - 1 \right);$$

$$V_{12} = + 11,6;$$

$$V_{12} = - 4,6 \text{ tons.}$$

The strains,  $V$ , in the verticals have been calculated under the supposition that the whole permanent load (weight of structure) is charged to the upper apexes. In reality, such is not true; and in consideration that about one-third of this load should be transmitted to the lower apexes, we increase the strains in verticals (in this case tie-rods) for 0,5 tons each, which changes the above results to the following:

$$V_1 (\text{max.}) = + 6,5 \text{ tons;}$$

$$V_2 (\text{max.}) = + 6,5 \text{ "}$$

$$V_3 \left\{ \begin{array}{l} (\text{max.}) = + 8,6 \\ (\text{min.}) = - 0,6 \end{array} \right\} V_3 = + 6,5;$$

$$V_4 \left\{ \begin{array}{l} (\text{max.}) = + 11,3 \\ (\text{min.}) = - 3,3 \end{array} \right\} V_4 = + 6,5;$$

$$V_5 \left\{ \begin{array}{l} (\text{max.}) = + 13,4 \\ (\text{min.}) = - 5,4 \end{array} \right\} V_5 = + 6,5;$$

$$V_6 \left\{ \begin{array}{l} (\text{max.}) = + 15,0 \\ (\text{min.}) = - 7,0 \end{array} \right\} V_6 = + 6,5;$$

$$V_7 \left\{ \begin{array}{l} (\text{max.}) = + 15,9 \\ (\text{min.}) = - 7,9 \end{array} \right\} V_7 = + 6,5;$$

$$V_8 \left\{ \begin{array}{l} (\text{max.}) = + 16,3 \\ (\text{min.}) = - 8,3 \end{array} \right\} V_8 = + 6,5;$$



fig. 170.

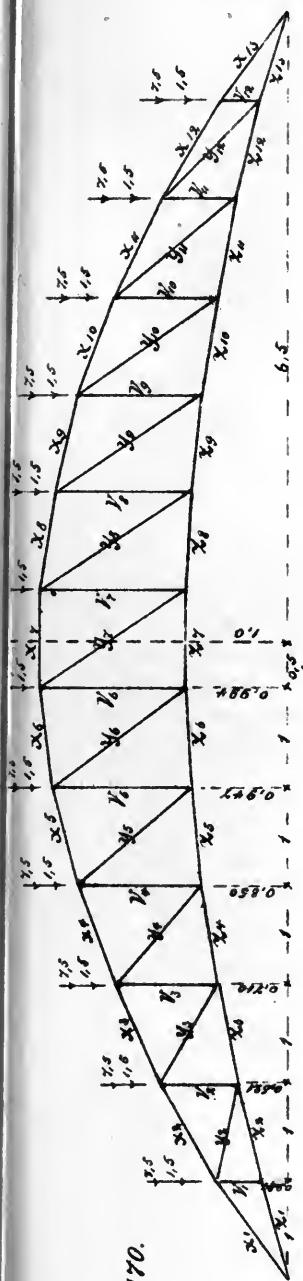


fig. 171

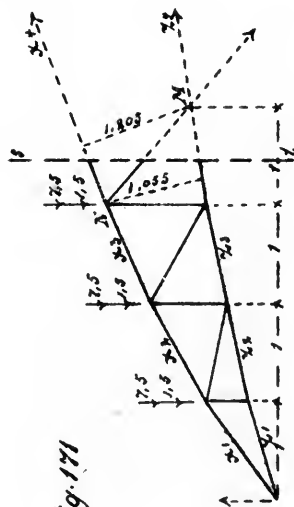


fig. 172

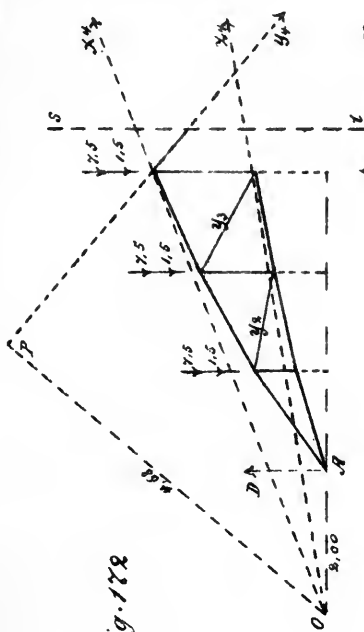


fig. 173

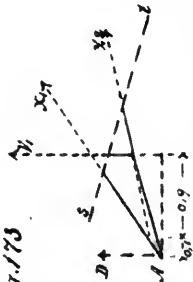


fig. 174

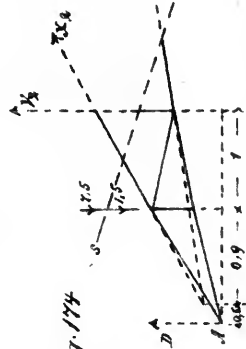
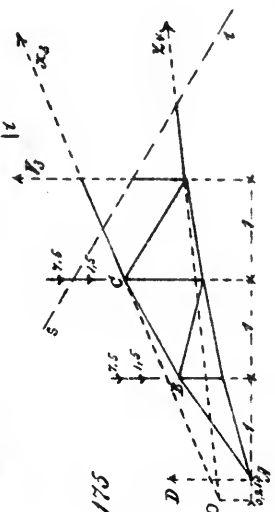
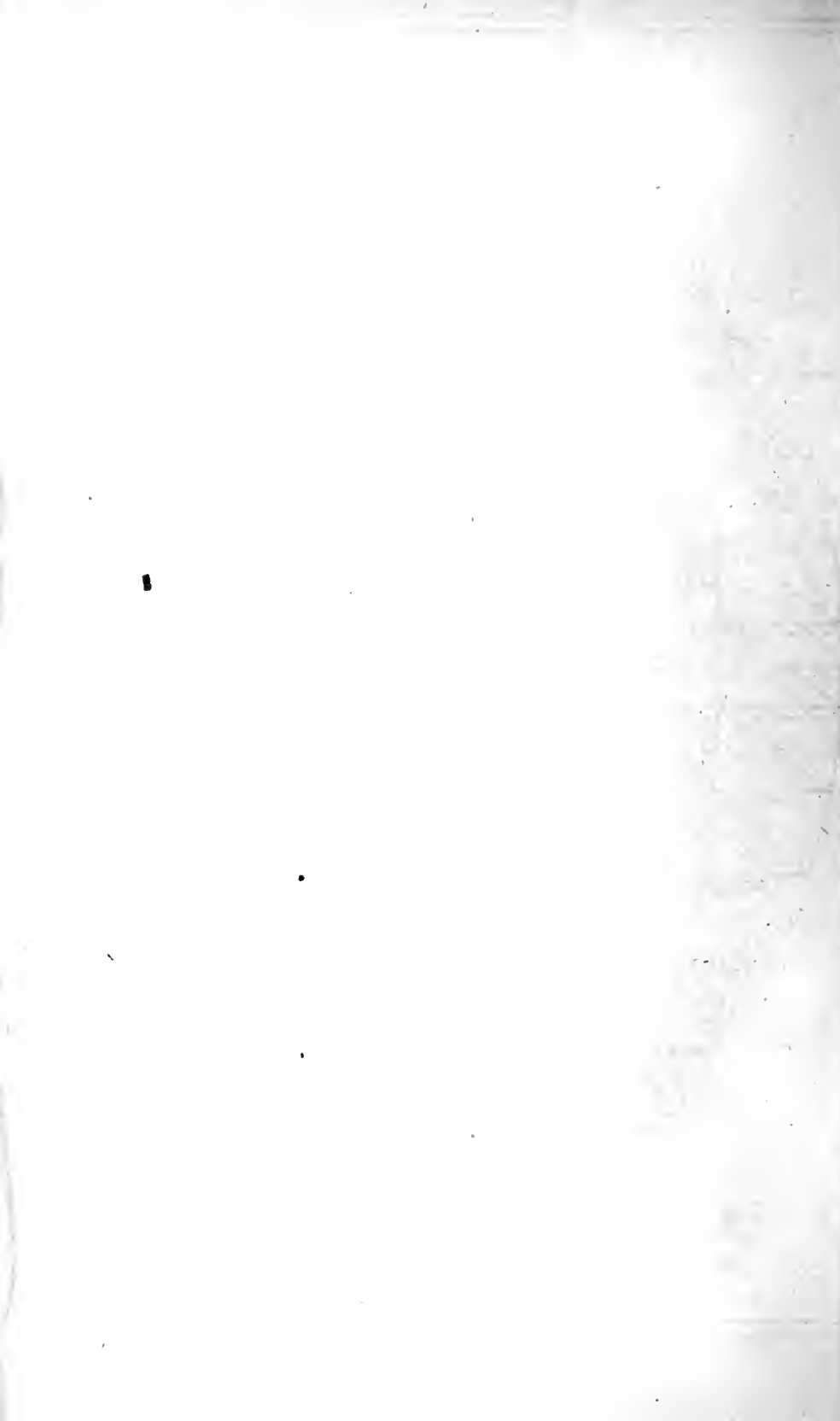
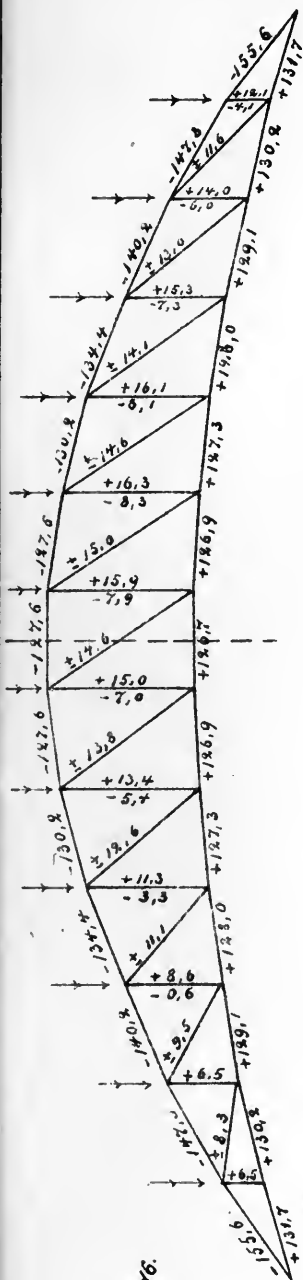
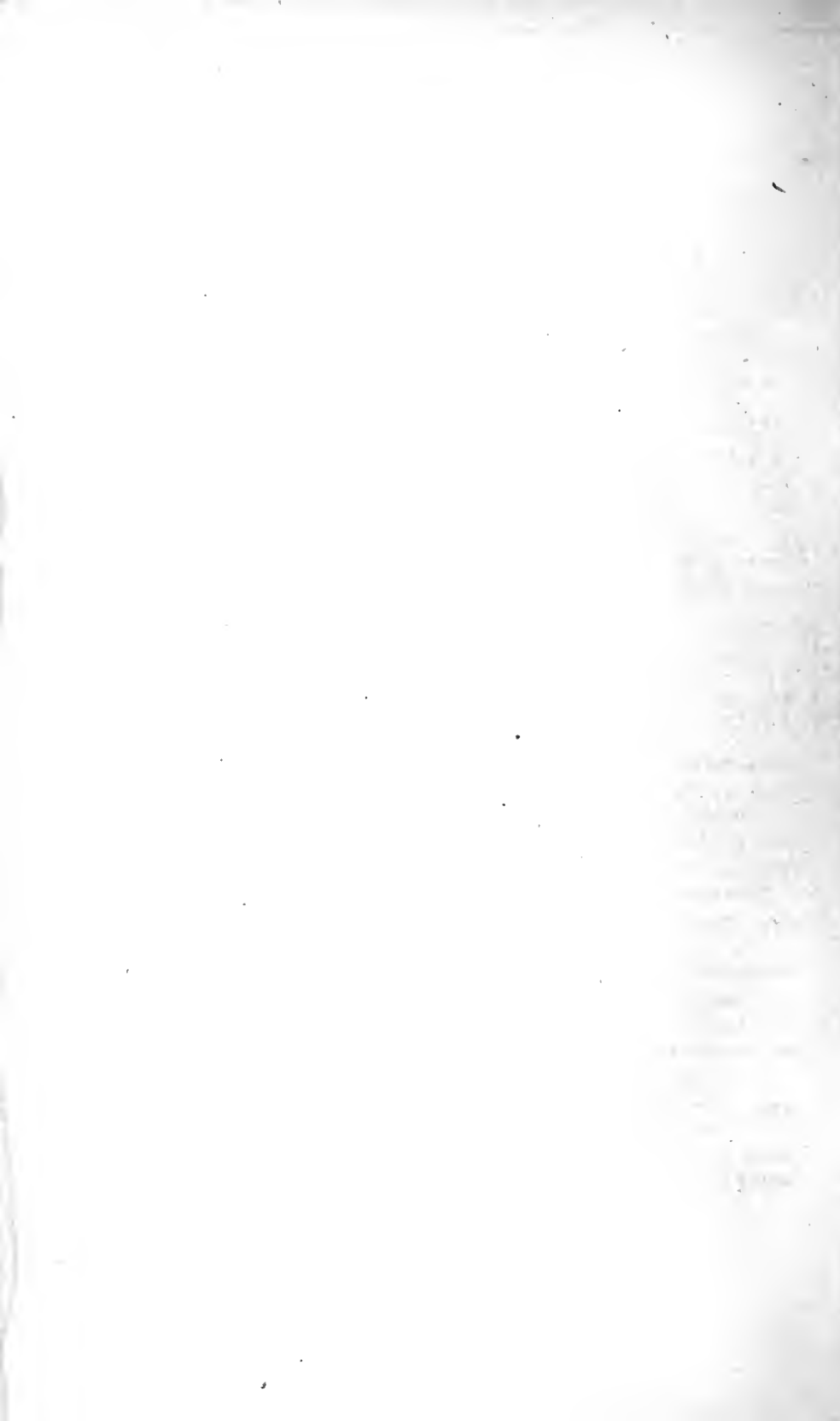


fig. 175









$$V_9 \left\{ \begin{array}{l} (\text{max.}) = + 16,1 \\ (\text{min.}) = - 8,1 \end{array} \right\} V_9 = + 6,5;$$

$$V_{10} \left\{ \begin{array}{l} (\text{max.}) = + 15,3 \\ (\text{min.}) = - 7,3 \end{array} \right\} V_{10} = + 6,5;$$

$$V_{11} \left\{ \begin{array}{l} (\text{max.}) = + 14,0 \\ (\text{min.}) = - 6,0 \end{array} \right\} V_{11} = + 6,5;$$

$$V_{12} \left\{ \begin{array}{l} (\text{max.}) = + 12,1 \\ (\text{min.}) = - 4,1 \end{array} \right\} V_{12} = + 6,5.$$

The results are combined in Fig. 176, and show that the strains in arches are independent of the direction of diagonals, because to both sides of the centre line their strain is the same, though the direction of the diagonal is not symmetrical to the centre line; therefore, for the definition of strain in  $x$  or  $z$ , it will make no difference if we choose in certain panels the left or right apex for the point of rotation.

#### TRANSFORMATIONS.

From the results above we see that for a single diagonal system the diagonals are strained both for tension and compression. For a girder with a single diagonal, but symmetrical system, we pursue the same course as in the parabolic girder, and it needs no further explanation to form from the preceding figure a girder with symmetrical diagonals, sloping right downward for one and right upward for the other half of girder; or, reversed, right upward for one and right downward for the other half of girder.

The transformation for a girder with crossed diagonals will be apparent from Skeleton 177, and it is only necessary to remark that, where the diagonals as tie-rods are constructed, for the verticals only the greatest compressive (—) strains come into consideration—observing from this that, per example, the minimum strain of  $V_4$  will be replaced by the greater minimum strain of  $V_9$  as its symmetrical opposite.

When the diagonals (for instance, by timbers) are constructed like braces as in Skeleton 178, designed by double lines, for the verticals only the maximum or greatest (+) strains come into consideration. The verticals are tie-rods in this case, acting for tensile strain.

[Plates 27 and 28—embracing Figs. 170 to 178.]

## E. THRUST CONSTRUCTION.

To form the equations of equilibrium, in the preceding calculations the reactive force of supports has formed an essential part, in place of which, by the thrust construction, the resulting force at the vertex comes into consideration. To define its intensity, a single weight,  $W$ , may be supposed to rest at  $E$  (Fig. 179) on an arch-shaped girder, fixed at the heels,  $A$  and  $B$ , and butted at  $F$ .

The weight,  $W$ , at a distance,  $x$ , from the right support, results in the force  $AW$ , intersecting the vertex  $F$ , and in the force  $WB$  toward the right support.

When  $R$  is the intensity in the direction  $AW$ , its components are  $180^\circ$ .]  $H$  and  $V$  (downward) for the left section, and  $H$  and  $V$  (upward) for the right section (Fig. 180<sup>a</sup>); and for the equilibrium we have

$$\text{left section,} \quad 0 = V.10 - H.4 \text{ (rot. } A\text{);}$$

$$\text{right section,} \quad 0 = V.10 + H.4 - Wx \text{ (rot. } B\text{),}$$

in which, by addition,

$$0 = V.20 - Wx, \quad \text{or } V = \frac{Wx}{20},$$

and by subtraction,

$$0 = H.8 - Wx, \quad \text{or } H = \frac{Wx}{8}.$$

When  $x = 10$  feet (*i. e.*, the weight,  $W$ , removed to the centre of the girder, Fig. 180<sup>a</sup>), then

$$V = \frac{W.10}{20}, \quad \text{or } V = \frac{W}{2};$$

$$H = \frac{W.10}{8}, \quad \text{or } H = \frac{5}{4}W,$$

(being for a weight,  $W = 100000$  lbs.);

$$V = 50000 \text{ lbs.,} \quad \text{and } H = 125000 \text{ lbs.}$$

Thus, having defined the forces at the vertex for a single weight,  $W$ , at the centre, for the diagonals we have the following equations of equilibrium, a cut,  $s, t$ , being supposed to separate the members next to the left support.

fig. 179

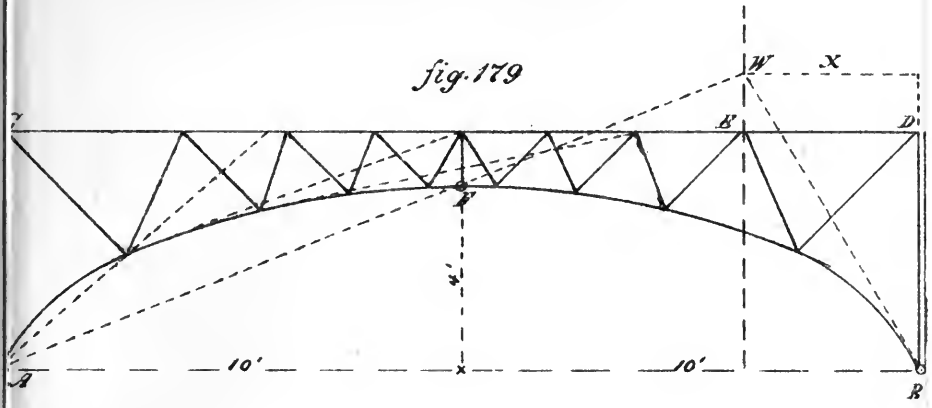


fig. 180<sup>a</sup>

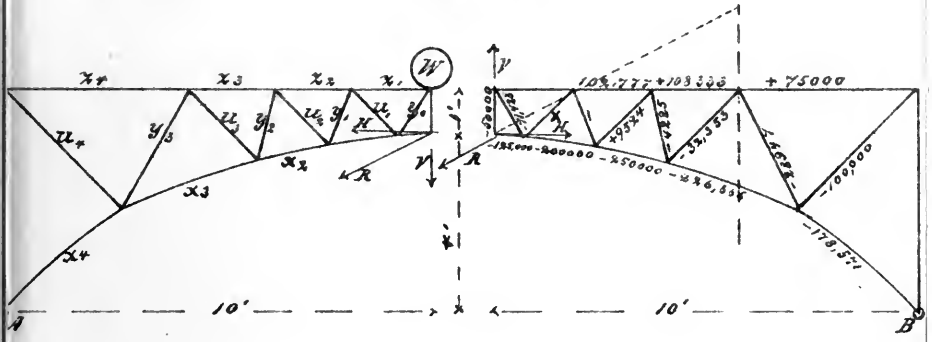
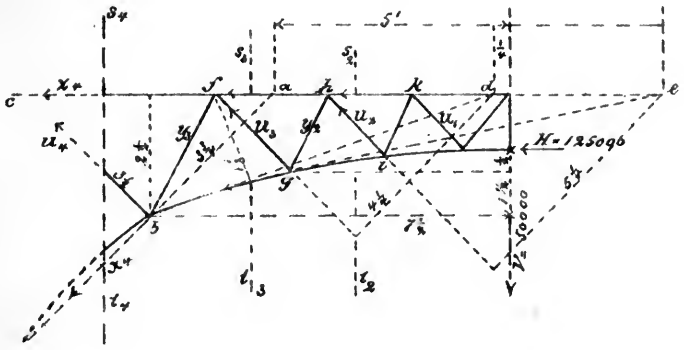
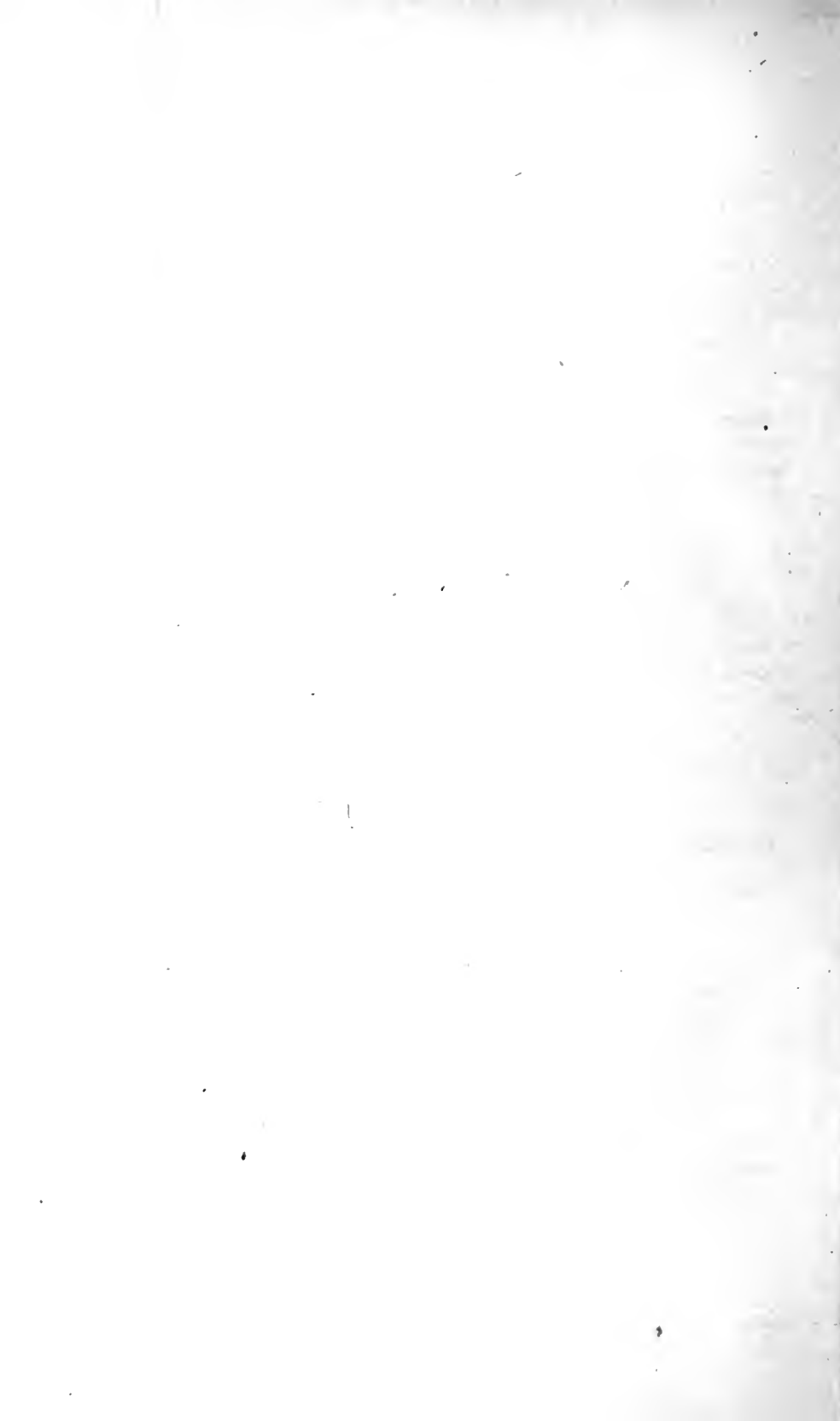


fig. 180<sup>b</sup>







$$180^{\circ}.] \quad 0 = u_4 \cdot 3\frac{1}{4} + H \times 1 + V \times 5 \text{ (rot. } a, \text{ Fig. } 180^b);$$

$$0 = u_4 \cdot 3\frac{1}{4} + 125000 + 250000;$$

$$u_4 = -100000.$$

$$0 = u_3 \cdot 4\frac{1}{4} + H \times 1 + V \times \frac{1}{4} \text{ (rot. } d);$$

$$0 = u_3 \cdot 4\frac{1}{4} + 125000 + 12500;$$

$$u_3 = -32353.$$

For  $u_2$ , the intersection,  $e$ , of the adjoining members,  $z$  of the upper and  $x$  of the lower string, is to the right of the centre; therefore, for the equilibrium,

$$0 = u_2 \cdot 5\frac{1}{4} + H \times 1 - V \times 3\frac{1}{2} \text{ (rot. } e);$$

$$0 = u_2 \cdot 5\frac{1}{4} + 125000 - 175000;$$

$$u_2 = +9524.$$

For the diagonals  $u_1$  and  $y_0$  we suppose the intersection to be in infinite distance (*i. e.*,  $z$  and  $x$  parallel); then  $H$  will have no leverage, and therefore will be without influence, and when the angle of  $y_0$  with a horizontal line  $= 45^{\circ}$ ,  $\sin 45^{\circ} = 0.707$ ,

$$-\frac{V}{y_0} = \sin 45, \quad \text{or } y_0 = -\frac{V}{0.707} = -\frac{50000}{0.707} = -71428;$$

$$\text{also,} \quad u_1 = +71428.$$

For  $y_2$  we have

$$0 = -y_2 \times 5\frac{1}{2} - V \times 3 + H \times 1 \text{ (rot. } e);$$

$$y_2 = -4255;$$

$$\text{also,} \quad y_3 = +28947.$$

The other diagonals,  $y$ , will be found in the same manner, and will be in numerical value the same as the diagonals  $u$ , in case their angle with the horizontal line is the same.

For the strains  $z$  in the upper string the rotation will be at the lower apexes; so for  $z_4$ ,

$$0 = -z_4 \times 2\frac{1}{2} - H \times 1\frac{1}{2} + V \times 7\frac{1}{2} \text{ (rot. } b);$$

$$0 = -z_4 \times 2\frac{1}{2} - 187500 + 375000;$$

$$z_4 = +75000;$$

$$0 = -z_3 \times 1\frac{1}{2} - H \times \frac{1}{2} + V \times 4\frac{1}{2} \text{ (rot. } g\text{)};$$

$$z_3 = +108333;$$

$$0 = -z_2 \times 1\frac{1}{2} - H \times \frac{1}{3} + V \times 2\frac{2}{3} \text{ (rot. } i\text{)};$$

$$z_2 = 102777.$$

In the same way, but with the rotation in the upper apexes, we have for the forces  $x$  in the lower stringer,

$$0 = x_4 \times 3\frac{1}{2} + H \times 1 + V \times 10 \text{ (rot. } c\text{)};$$

$$x_4 = -178571;$$

$$0 = x_3 \times 1\frac{1}{2} + H \times 1 + V \times 6 \text{ (rot. } f\text{)};$$

$$x_3 = -226666;$$

$$0 = x_2 \times 1\frac{1}{2} + H + V \times 3\frac{1}{2} \text{ (rot. } h\text{)};$$

$$x_2 = -250000;$$

$$0 = x_1 \times 1\frac{1}{2} + H \times 1 + V \times 2 \text{ (rot. } k\text{)};$$

$$x_1 = -200000.$$

The results are given in the right section of Fig. 180<sup>a</sup>.

For a combined (permanent and rolling) load another example will explain the definition of strains:

Plate 30,  
Fig. 181.]

Span = 72 feet, or 24 metres; (Fig. 181.)

permanent load = 2 tons for each apex;

rolling load = 6 tons for each apex.

To ascertain the maximum strain of the single members we again first take into consideration what influence a single load,  $Q$ , upon the structure will have.

For a single weight,  $Q$ , to the right of the centre line, and the produced pressure,  $R$ , toward the left abutment, it will be observed that the reaction of the left support is in the line  $AS$ , the prolongation of which intersects in  $P$  with a vertical line in  $Q$ , the reaction of  $A_1$  being also directed toward  $P$ .

The pressure at the link in the vertex  $S$  we divide in its horizontal and vertical components,  $H$  and  $V$ , and when the moments are formed each for one-half of the structure in relation to their respective supports, we find from Fig. 182,

$$0 = V.12 + H.4 - Q.3 \text{ for the right section (rot. } A_1);$$

$$0 = V.12 - H.4 \text{ for the left section (rot. } A).$$

These equations, when at one time added and at another subtracted, result in

$$V = \frac{Q}{8}, \quad \text{and } H = \frac{3}{8}Q.$$

As by this mode of observation we are enabled to ascertain the influence of a weight,  $Q$ , upon the whole system, for the definition of strain in a certain member of the structure we make a cut,  $st$ , and form for the considered section the equation of moments.

#### DEFINITION OF STRAIN $x$ IN THE HORIZONTAL FLANGES.

For a point of rotation we take the foot,  $E$ , of the diagonal. (B, E, Fig. 182.)

Each weight to the left of the centre line produces a pressure in the vertex,  $S$ , the direction of which is from  $A_1$  toward  $S$ , to keep the section in its position.

The components of this pressure ( $H$  and  $V$ ) aim to turn to the left round  $A$ , similar to the strain  $x_1$  itself, thereby making  $x_1$  compressive.

Each weight to the right of the centre line produces for the left part a pressure in the vertex, the direction of which is through the point of rotation,  $E$ , and for this reason has no influence.

For the greatest compression, therefore, we consider one-half of the girder, containing the flange in question, charged with a full load. The other half can be either loaded or unloaded without influence, as already stated.

183.] Both halves being loaded, we have, from Fig. 183, for the pressure in the vertex,

$$0 = V.12 + H.4 - 4 \times 12 - 8(9 + 6 + 3) \text{ (b) rot. } A_1;$$

$$0 = V.12 - H.4 + 4 \times 12 + 8(9 + 6 + 3) \text{ (a) rot. } A;$$

$$V = 0, \quad \text{and } H = 48.$$

184.] From this for  $x_1$  (rot.  $r$ .  $E$ , Fig. 184),

$$0 = -x_1.3.5 - 48 \times 3 + 8(3 + 6) + 4 \times 9;$$

$$x_1 = -10.29 \text{ tons;}$$

and in the same way,

$$0 = -x_2 \cdot 2,5 - 48 \times 2 + 8 \times 3 + 4 \times 6;$$

$$x_2 = -19,2 \text{ tons};$$

$$0 = -x_3 \cdot 1,5 - 48 \times 1 + 4 \times 3;$$

$$x_3 = -24 \text{ tons};$$

$$0 = -x_4 \cdot 0,5;$$

$$x_4 = 0.$$

### DEFINITION OF STRAIN $y$ IN THE DIAGONALS.

When for a section (Fig. 186) the strain in the diagonal,  $y_2$ , is to be calculated, the first thing is to define the strain in the vertex.

185.] For  $y_2$ , maximum, the apexes 3 and 4 ought to be loaded. The others are indifferent, and we have for the strain in the vertex (Fig. 185),

$$0 = -V \cdot 12 + H \cdot 4 - 1 \times 12 - 2(9 + 6 + 3) \text{ (rot. } A_1);$$

$$0 = -V \cdot 12 - H \cdot 4 + 1 \times 12 + 2(9 + 6 + 3) + 6(9 + 6) \text{ (rot. } A);$$

$$V = 3,75, \quad \text{and } H = 23,25,$$

which gives for Fig. 186 the equation of equilibrium.

$$0 = y_2 \cdot 6,72 + 23,25 \times 0,5 + 3,75 \times 1,5 - 1 \times 1,5 - 8(4,5 + 7,5 \text{ (rot. } F));$$

$$y_2 \text{ (max.)} = +11,94 \text{ tons.}$$

186.] For  $y_2$ , (min.), the apexes 3 and 4 ought to be unloaded, the second loaded. The others again are indifferent, and may be unloaded.

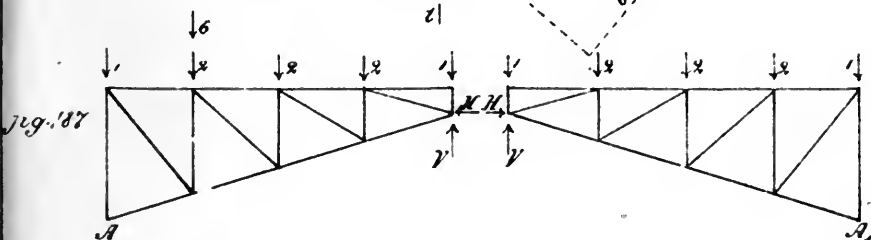
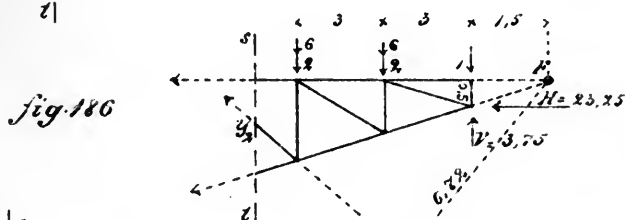
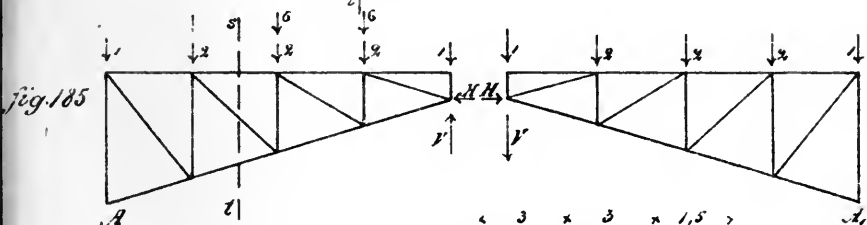
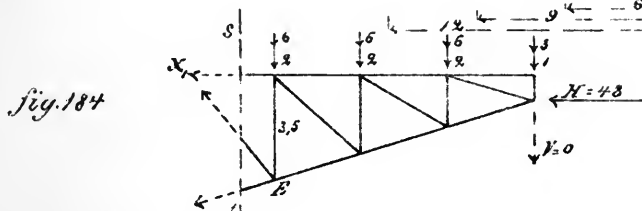
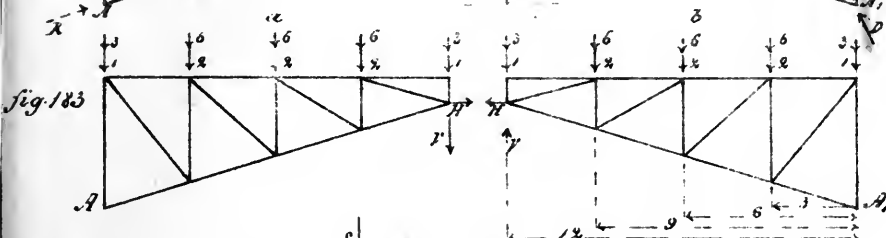
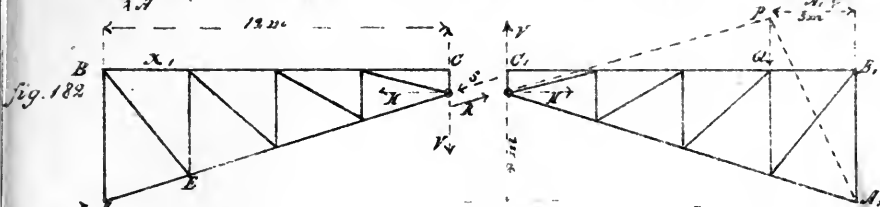
187.] For the strain in the vertex is from the equations formed from Fig. 187,

$$0 = -V \cdot 12 + H \cdot 4 - 1 \times 12 - 2(9 + 6 + 3) \text{ (rot. } r \cdot A_1);$$

$$0 = -V \cdot 12 - H \cdot 4 + 1 \times 12 + 2(9 + 6 + 3) + 6 \times 3 \text{ (rot. } r \cdot A);$$

$$V_0 = 0,75, \quad \text{and } H = 14,25;$$

Plate 31,] And thus we find for the moments upon the section  
Fig. 188.] (Fig. 188),





$$0 = y_2 \cdot 6,72 + 0,75 \times 1,5 + 14,25 \times 0,5 - 1 \times 1,5 - 2(4,5 + 7,5);$$

$$y_2 (\text{min.}) = + 2,75 \text{ tons.}$$

In the same manner we find for  $y_1 (\text{max.})$  the following equations:

With a full load,  $V = 0$ , and  $H = 48$ ;

$$\text{therefore, } 0 = y_1 \cdot 10,25 + 48 \times 0,5 - 4 \times 1,5 - 8(4,5 + 7,5 + 10,5);$$

$$y_1 (\text{max.}) = + 15,8 \text{ tons.}$$

$y_1 (\text{min.})$  does not exist, because in this diagonal no compression can be produced.

For  $y_3 (\text{max.})$  only the fourth apex should be loaded.

$$V = 2,25, \quad \text{and } H = 18,75;$$

$$0 = y_3 \cdot 3,35 + 2,25 \times 1,5 + 18,75 \times 0,5 - 1 \times 1,5 - 8 \times 4,5;$$

$$y_3 (\text{max.}) = + 7,39 \text{ tons.}$$

For  $y_3 (\text{min.})$ , when only the second and third apexes are loaded,

$$V = 2,25, \quad \text{and } H = 18,75;$$

$$0 = y_3 \cdot 3,35 + 2,25 \times 1,5 + 18,75 \times 0,5 - 1 \times 1,5 - 2 \times 4,5;$$

$$y_3 (\text{min.}) = - 0,67 \text{ tons.}$$

For  $y_4$ , a compressive strain will not exist, and we have only  $y_4 (\text{min.})$  to calculate, for which Apexes 2, 3 and 4 are loaded

$$V = 4,5, \quad \text{and } H = 25,5;$$

$$0 = y_4 \cdot 0,738 + 4,5 \times 1,5 + 25,5 \times 0,5 - 1 \times 1,5;$$

$$y_4 (\text{min.}) = - 24,4 \text{ tons.}$$

#### CALCULATION OF THE TENSILE STRAINS $z$ IN THE LOWER FLANGES.

For  $z_3$  we find, after short contemplation, that  $st$ , in Fig. 189, is 189.] the separating line, in which a weight,  $q$ , produces no strain in  $z_3$ . Every load to the right of this line produces compression, and every load to the left produces tension, making  $z_3$  positive; therefore we have for  $z_3 (\text{max.})$  the strain in the vertex from Fig. 189,

$$0 = -V.12 + H.4 - 1 \times 2 - 2(9 + 6 + 3) \text{ (rot. } r. A_1);$$

$$0 = -V.12 - H.4 + 1 \times 12 + 2(9 + 6 + 3) + 6(6 + 3) \text{ (rot. } r. A);$$

$$V = 2,25, \quad \text{and } H = 18,75;$$

190.] and from Fig. 190, for the equations of equilibrium,

$$0 = z_3.2,37 - 2,25 \times 6 + 18,75 \times 0,5 + 1 \times 6 + 2 \times 3 \text{ (rot. } I);$$

$$z_3 \text{ (max.)} = -3,32 \text{ tons.}$$

191.] For  $z_3$  (min.), from Fig. 191,

$$0 = V.12 + H.4 - 1 \times 12 - 2(9 + 6 + 3) - 3 \times 12 - 6(9 + 6 + 3) \text{ (rot. } r. A_1);$$

$$0 = V.12 - H.4 + 1 \times 12 + 2(9 + 6 + 3) + 3 \times 12 + 6 \times 9 \text{ (rot. } r. A);$$

$$V = 2,25, \quad \text{and } H = 41,25;$$

192.] and from this,

$$0 = z_3.2,37 + 2,25 \times 6 + 41,25 \times 0,5 + 4 \times 6 + 8 \times 3 \text{ (rot. } r. I, \text{ Fig. 192);}$$

$$z_3 \text{ (min.)} = -34,6 \text{ tons.}$$

In the same manner for  $z_1$ , for which the separating line in the first apex and the minimum strain by a full load,

$$V = 0, \quad \text{and } H = 48;$$

$$0 = z_1.4,27 + 48 \times 0,5 + 4 \times 12 + 8(9 + 6 + 3);$$

$$z_1 \text{ (min.)} = -50,6 \text{ tons};$$

and for  $z_2$ , separating line between Apexes 2 and 3,

$$V = 0,75, \quad \text{and } H = 14,25;$$

$$0 = z_2.3,32 - 0,75 \times 9 + 14,25 \times 0,5 + 1 \times 9 + 2(6 + 3);$$

$$z_2 \text{ (max.)} = -8,25 \text{ tons};$$

and for the minimum, where

$$V = 0,75, \quad \text{and } H = 45,75;$$

$$0 = z_2.3,32 + 0,75 \times 9 + 45,75 \times 0,5 + 4 \times 9 + 8(6 + 3);$$

$$z_2 \text{ (min.)} = -41,45 \text{ tons.}$$



fig. 188

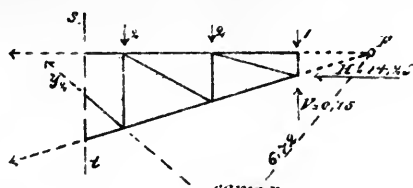


fig. 189

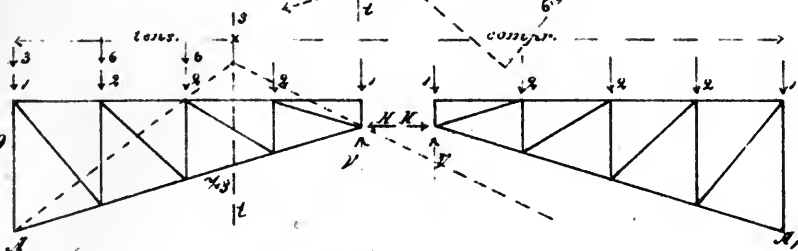


fig. 190

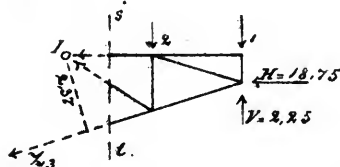


fig. 191

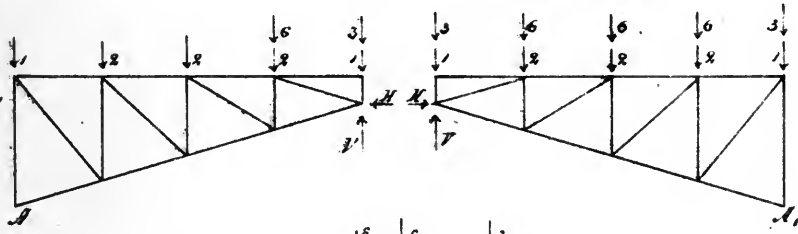


fig. 192

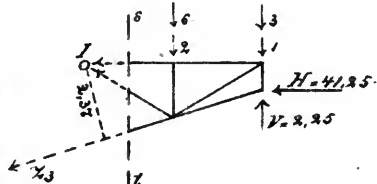


fig. 193

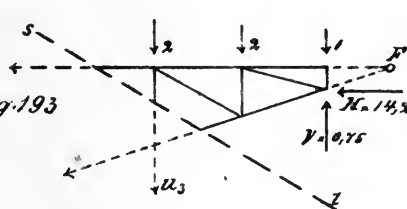


fig. 194

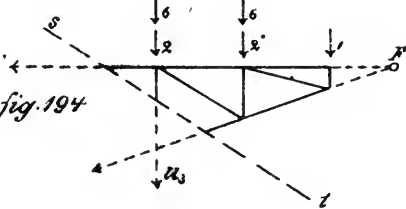
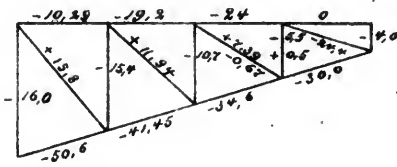
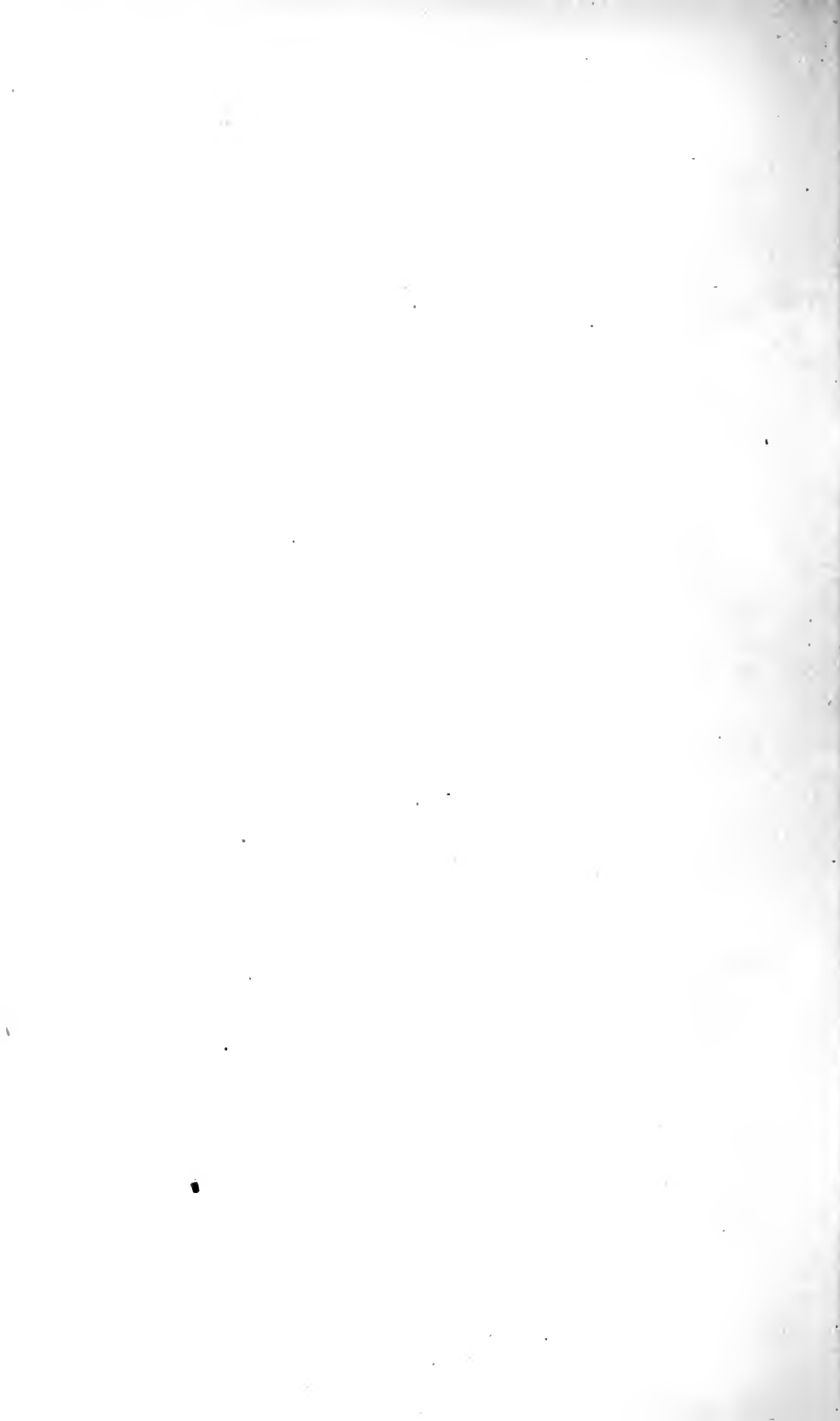


fig. 195





For  $z_4$ , separating the line between Apexes 4 and 5,

$$V = 4,5, \quad \text{and } H = 25,5;$$

$$0 = z_4 \cdot 1,423 - 4,5 \times 3 + 25,5 \times 0,5 + 1 \times 3;$$

$$z_4 (\text{max.}) = -1,58 \text{ tons.}$$

For the minimum,

$$V = 4,5, \quad \text{and } H = 34,5;$$

$$0 = z_4 \cdot 1,423 + 4,5 \times 3 + 34,5 \times 0,5 + 4 \times 3;$$

$$z_4 (\text{min.}) = -30,0 \text{ tons.}$$

### CALCULATION OF THE VERTICALS $u$ .

For  $u_3$ , per example, we have from Fig. 187,

$$V = 0,75, \quad \text{and } H = 14,25;$$

193.] and the equation of equilibrium from Fig. 193,

$$0 = -u_3 \cdot 7,5 + 0,75 \times 1,5 + 14,25 \times 0,5 - 1 \times 1,5 - 2(4,5 + 7,5) (\text{rot. } r. F);$$

$$u_3 (\text{max.}) = -2,3 \text{ tons};$$

For the minimum from Fig. 185,

$$V = 3,75, \quad \text{and } H = 23,25;$$

194.] and from Fig. 194,

$$0 = -u_3 \cdot 7,5 + 3,75 \times 1,5 + 23,25 \times 0,5 - 1 \times 1,5 - 8(4,5 + 7,5) (\text{rot. } r. F);$$

$$u_3 (\text{min.}) = -10,7 \text{ tons.}$$

In the same way we find for  $u_1$ , where  $V = 0$ , and  $H = 48$ ,

$$u_1 (\text{min.}) = -16,0 \text{ tons.}$$

For  $u_2$ ,  $V = 0$ , and  $H = 48$ ;

$$u_2 (\text{min.}) = -15,4 \text{ tons};$$

and for  $u_4$ , where  $V = 2,25$ , and  $H = 18,75$ ;

$$0 = -u_4 \cdot 4,5 + 2,25 \times 1,5 + 18,75 \times 0,5 - 1 \times 1,5 - 2 \cdot 4,5;$$

$$u_4 (\text{max.}) = +0,5 \text{ tons.}$$

For the minimum,

$$V = 2,25, \quad \text{and } H = 18,75;$$

$$0 = -u_4 \cdot 4,5 + 2,25 \times 1,5 + 18,75 \times 0,5 - 1 \times 1,5 - 8 \times 4,5;$$

$$u_4 (\text{min.}) = -5,5 \text{ tons};$$

$$u_3 = -4 \text{ tons.}$$

195.] The results are combined in Fig. 195.

## II. CALCULATION OF A TRUSS SUSTAINING A DOME.

Plate 32, ] For the construction of a dome (Figs. 196-7), the  
Figs. 196-7.] distribution of the load at the apexes should be first considered. The ribs not being parallel, but intersecting at the vertex, therefore the variable load increases toward the base, *AB*, in the same relation as the sections of the horizontal circles drawn through the apexes.

These sections are proportional to their radii. When, therefore, their length is measured, and at a certain apex the load is defined, the proportion of the radius of this point compared with any other radius will give the weight or load at such apex. The weight of the rib itself will be the only constant load. Every other weight, as sheeting, snow and wind-pressure, should be calculated as a variable load—for instance, when the sheeting is displaced at one side for repairs.

This problem may be still further explained by the following example: On a dome of 100 yards span, the outlines may form a semi-globe whose radius = 51 yards. Its area being 16338 square yards, each of the eight ribs will sustain the weight of an area = 2042 square yards. The load, including the weight of sheeting, snow and wind-pressure, estimated at 470 lbs. per square yard, gives 480 tons (at 2000 lbs.) for each rib.

The weight of a rib whose outside and inside circles (chords) are 2 yards apart may be estimated = 60 tons, this being the permanent load, which when equally distributed to the panels, 15 in number, will give for each apex a permanent load of 4 tons.

For the proportion of the variable load, the distances of the

apexes from the vertical centre line require to be measured, resulting in

0	5,3	10,6	15,8	20,7	25,5	30	34,1	37,9	41,3	44,2	46,6	48,5	49,9	50,7	51
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Proportional to these figures is the variable load; therefore, when the whole sum (being 512) is divided into the whole load = 480 tons, and the result multiplied by those figures, then the variable load for each apex will be

5	9,9	14,8	19,4	23,9	28,1	32	35,5	38,7	41,4	43,7	45,5	46,8	47,6
1	2	3	4	5	6	7	8	9	10	11	12	13	14

This being defined, for the further calculation we suppose the ribs on their supports secured against the horizontal thrust by means of a horizontal wrought-iron band (ring); then the supports will sustain only a vertical pressure equal to the weight of the structure.

Each pair of opposite ribs thus fixed at the heels, and resting at the top against a globe or universal joint (providing expansion and contraction), will show conformity to the preceding example. In the calculation, therefore, we can follow the same principles.

So we find again by an unloaded and also by a completely loaded state the vertical pressure at the vertex = 0.

The horizontal force will be defined in forming the equation for all the moments of the loaded apexes in regard to the point *A* of support, their levers being

50	44,7	39,4	34,2	29,3	24,5	20	15,9	12,1	8,7	5,8	3,4	1,5	0,1	-0,7
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

For an unloaded state of ribs it will be

$$H. 50 = 4 \left( \frac{5,9}{2} + 44,7 + 39,4 + \dots + 1,5 + 0,1 - 0,7 \right) = 1056;$$

$$H = 21,12;$$

but for a loaded state,

$$\begin{aligned} H. 50 = & 4 \left( \frac{5,9}{2} + 47,7 + 39,4 + \dots + 1,5 + 0,1 - 0,7 \right); \\ & + 5 \times 44,7 + 9,9 \times 39,4 + \dots + 45,5 \times 1,5 + 46,8 \times 0,1) - \\ & 47,6 \times 0,7. \end{aligned}$$

These figures show the moments of the movable load in regard to the point *A*, and for use in the following the value of each may be stated here:

223,5	390	506,2	568,4	585,6	562	508,8	429,6	336,7	240,1	148,6	68,3	4,7	-33,3
1	2	3	4	5	6	7	8	9	10	11	12	13	14

From this we find for *H* in the preceding equation,

$$H \times 50 = 1056 + 223,5 + 390 + \dots + 68,3 + 4,7 - 33,3 = 5595;$$

$$H = 111,9.$$

#### CALCULATION OF STRAINS $x$ OF THE OUTSIDE ARCH.

198.] To explain the calculation, we choose the section of the arch between the Apexes 5 and 6, *M* to be the point of rotation. (Fig. 198.)

The vertical line at *E*, distinguishing the influence of the load upon tensile and compressive strain, can be constructed in making a line from the opposite support through *S*, and another line from *A* through the point of rotation, *M*. The distance of this line from the vertical centre line is 13 yards, being between the Apexes 2 and 3.

The tension,  $x$ , will be a maximum when the points 3, 4, 5... 14 are in an unloaded state, and the others in a loaded state; then for the pressure at the vertex for the formation of moments of both opposite ribs,

$$H. 50 = 5595 - V \times 50 \text{ (for the rib to the right);}$$

$$H. 50 = 5595 + V. 50 - 506 - 568 - 586 - \dots - 4,7 + 33,3 \text{ (for the rib to the left);}$$

$$H = 72,7; \quad V = 39,2.$$

Plate 33,] From this, for  $x$  (max.), from Fig. 199,  
Fig. 199.]

$$0 = -x. 2 - 72,7 \times 8,9 + 39,2 \times 26,7$$

$$+ 4 \left( \frac{26,7}{2} + 21,4 + 16,1 + 10,9 + 6 + 1,2 \right);$$

$$+ 5 \times 21,4 + 9,9 \times 16,1 \text{ (rot. } M \text{);}$$

$$x \text{ (max.)} = + 470,9 \text{ tons.}$$

fig. 196

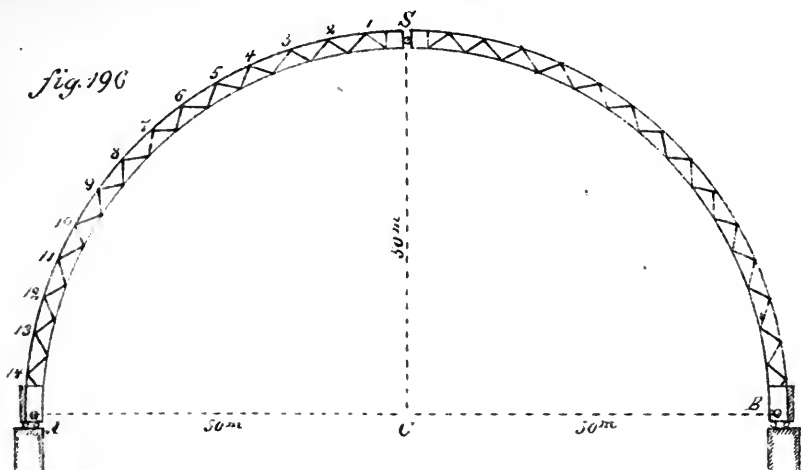


fig. 197.

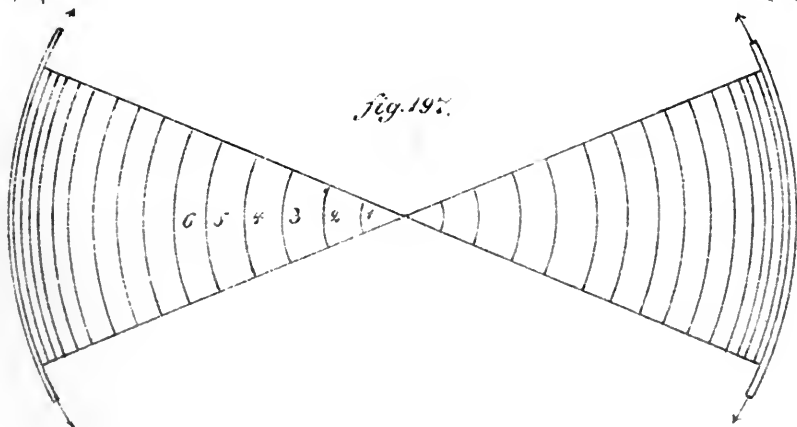
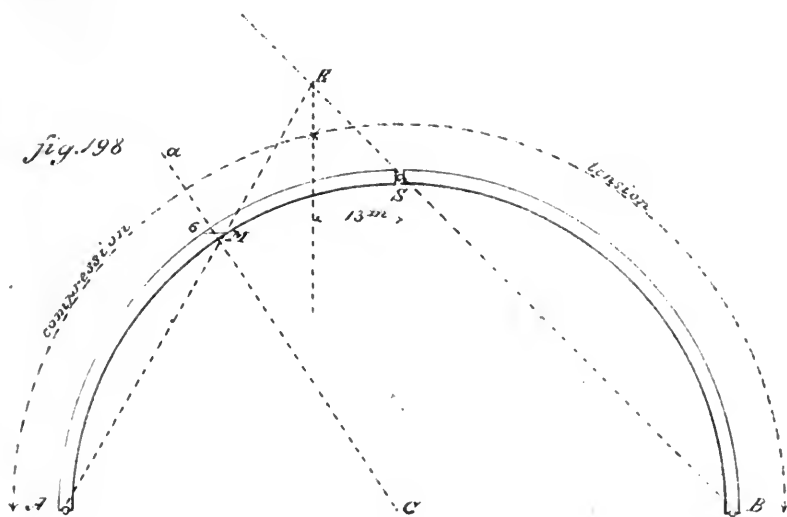


fig. 198







For  $x$  (min.) only the Apexes 3, 4, 5... 14 are supposed to be loaded; then the components of the resulting strain at the vertex of the ribs will be found in forming the equations for each of the two sides, adding for the left side to the permanent load the values of the variable load from Apexes 3 to 14.

$$0 = H \times 50 - V \times 50 - 1056;$$

$$0 = -H \times 50 - V. 50 + 1056 + 506 + 568 + 586 + \dots + 4,7 - 33,3;$$

$$H = 60,3, \quad \text{and } V = 39,2.$$

200.] Then for  $x$  (min.), from Fig. 200,

$$0 = -x. 2 - 60,3 \times 8,9 - 39,2 \times 26,7 + 4 \left( \frac{26,7}{2} + 21,4 + 16,1 + 10,9 + 6 + 1,2 \right)$$

$$+ 14,8 \times 10,9 + 19,4 \times 6 + 23,9 \times 1,2;$$

$$x \text{ (min.)} = -500,6 \text{ tons.}$$

#### CALCULATION OF STRAINS $z$ OF THE INSIDE ARCH.

The same panel may serve for calculation, being the section opposite Apex 6.

For the equation of equilibrium of this section, the point of rotation will be in 6. To find the vertical line, distinguishing the action of the load upon tensile or compressive strain, the direction from  $A$  through 6 and from  $B$  through  $S$  gives the point of intersection,  $F$  (Fig. 201), being 17,3 yards from the vertical centre line between Apexes 3 and 4.

For  $z$  (max.), only the points 4, 5... 14 should be loaded; then, for the components at the vertex,

$$0 = H. 50 - V. 50 - 1056;$$

$$0 = H. 50 - V. 50 + 1056 + 568 + 586 + \dots + 4,7 - 33,3;$$

$$H = 55,3, \quad \text{and } V = 34,2.$$

202.] Now, from Fig. 202,

$$0 = z. 2 - 55,3 \times 8,74 - 34,2 \times 30;$$

$$+ 4 \left( \frac{30}{2} + 24,7 + 19,4 + 14,2 + 9,3 + 4,5 \right)$$

$$+ 19,4 \times 9,3 + 23,9 \times 4,5;$$

$$z \text{ (max.)} = + 436,5 \text{ tons};$$

and further, for the components at the vertex, for  $z$  (min.), the Apexes 4, 5 ... 14 are to be unloaded, all the others to be loaded; and for the negative value of the moments for Apexes 4 and 5, added to the sum of moments of the left rib, when entirely loaded,

$$0 = H. 50 + V. 50 - 5595;$$

$$0 = - H. 50 + V. 50 + 5595 - 568 - 586 - \dots 4,7 + 33,3;$$

$$H = 77,7, \quad \text{and } V = 34,2.$$

203.] Now, according to Fig. 203,

$$0 = z. 2 - 77,7 \times 8,74 + 34,2 \times 30$$

$$+ 4 \left( \frac{3}{2} + 24,7 + 19,4 + 14,2 + 9,3 + 4,5 \right)$$

$$+ 5 \times 24,7 + 9,9 \times 19,4 + 14,8 \times 14,2;$$

$$z \text{ (min.)} = - 610,5 \text{ tons.}$$

#### CALCULATION OF THE DIAGONALS $y$ .

The diagonal between 9 and 10, intersecting with the outside arch at Apex 10, may serve for explanation.

Plate 34,]  
Fig. 204.] In the cut  $st$  (Fig. 204), separating the diagonal and the arches, the point of intersection of the latter will be again in infinite distance (see calculation of trusses with parallel top and bottom flanges) in the tangent of a circle half way between the outside and inside arches.

This tangent forms an angle of  $58\frac{1}{2}$  degrees with the vertical line at the centre, or with the horizontal line  $CA$ .

The forces parallel to the tangent have no influence upon  $y$ , their direction going in infinite distance through the intersection of the inside and outside arches.

Therefore, all the forces acting upon the section  $Sst$  should be separated in forces right-angled and parallel to the tangent, the parallel forces to be omitted.

The vertical separating line of the weights acting upon compression or tension will be found in drawing a line through  $A$  (Fig. 204), parallel to the tangent, and through  $BS$ , intersecting at  $J$ .  $A$

fig. 199

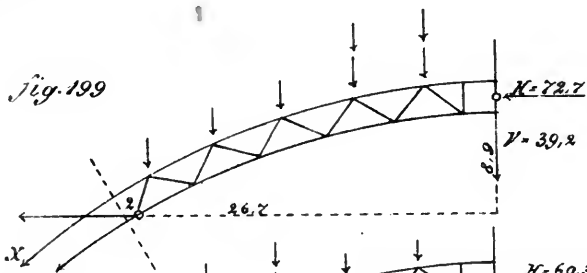


fig. 200

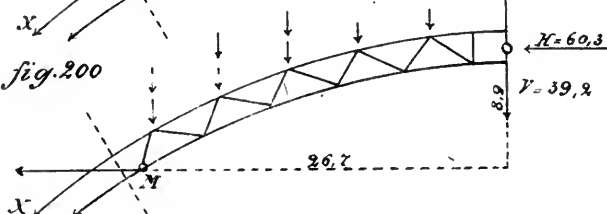


fig. 201.

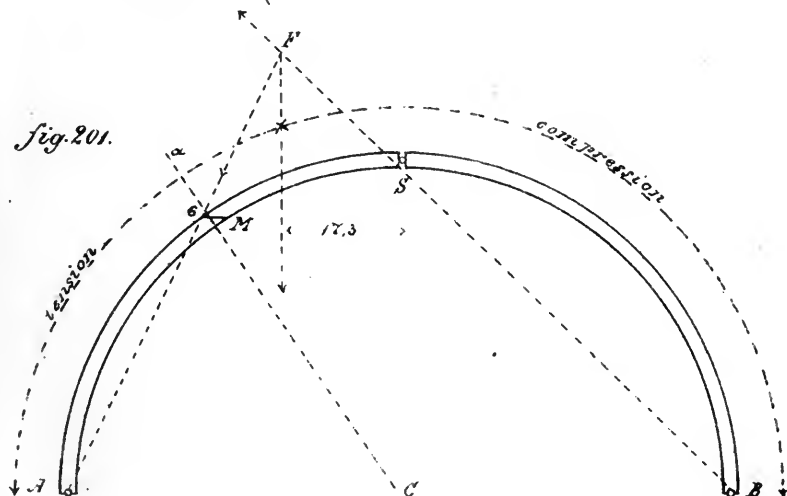


fig. 202

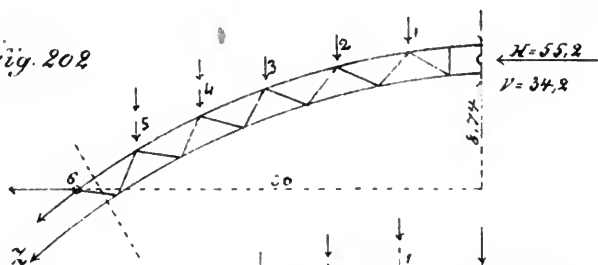
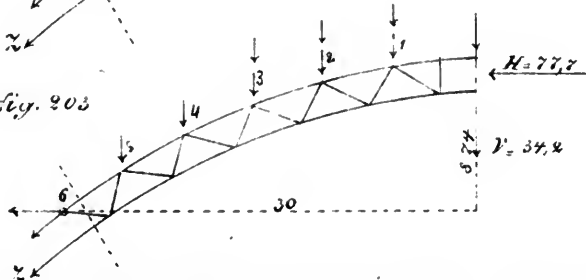
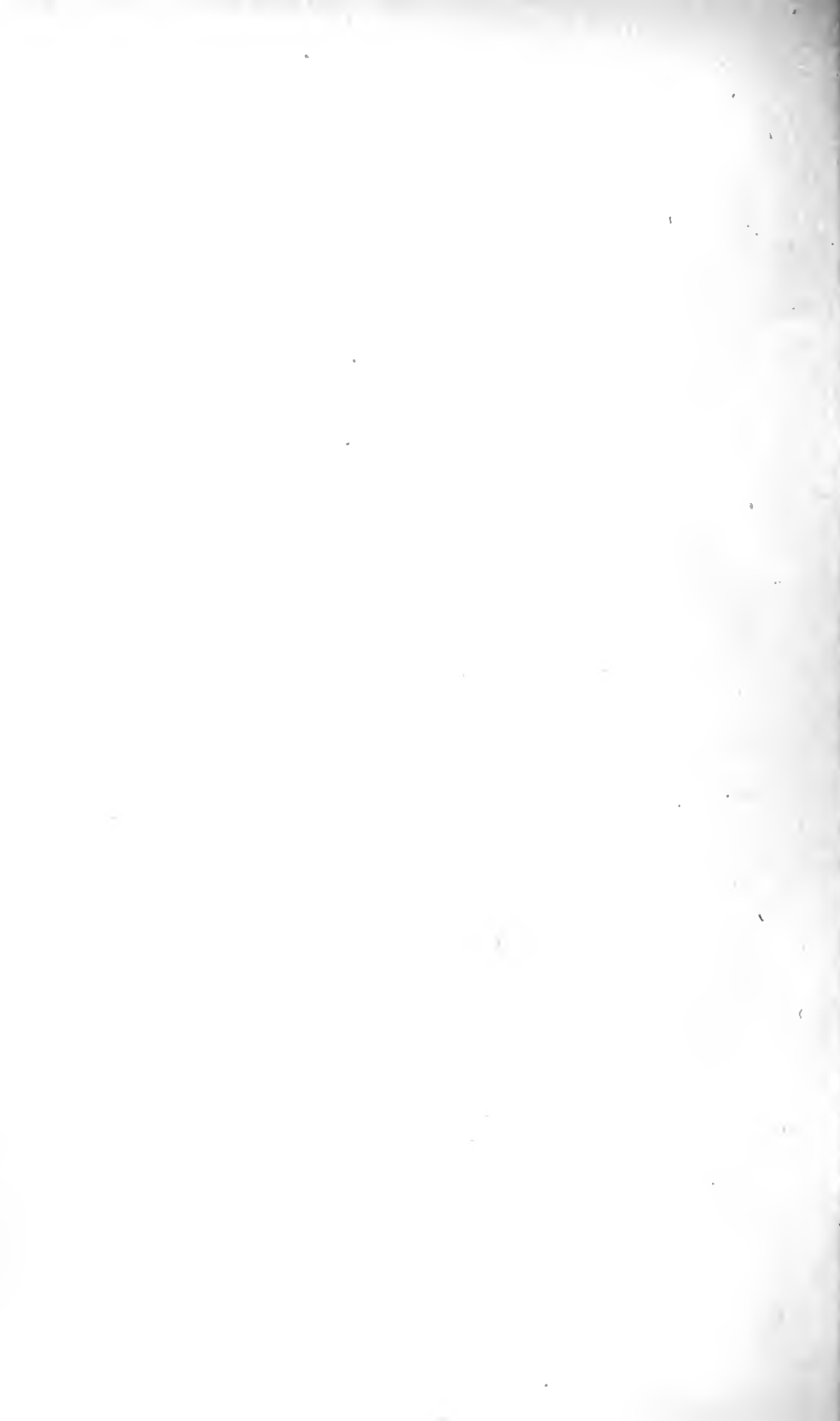


fig. 203





weight suspended in the vertical direction through  $J$  creates with its pressure at the vertex a resulting strain, being without influence upon the diagonal,  $y$ .

Every load to the right of the vertical line in  $J$  creates compression, and every load to the left to the separating line,  $st$ , produces tension. From this point down to the support,  $A$ , compression is produced.

The distance,  $J$ , from the vertex being 12 yards (*i.e.*, between the second and third apexes), the force,  $y$ , will be a maximum when the apexes 3, 4, 5, 6, 7, 8 and 9 are loaded.

For the forces at the vertex,

$$0 = H.50 - V.50 - 1056;$$

$$0 = -H.50 - V.50 + 1056 + 506 + 568 + 586 + 562 + 509 + 430 + 337;$$

$$H = 56,1 \text{ tons,} \quad \text{and } V = 35 \text{ tons.}$$

205.] From Fig. 205, for the equilibrium, all the forces acting in the direction  $N$  being 0,

$$0 = N + 56,1 \times \cos 31\frac{1}{2}^\circ + 35 \times \sin 31\frac{1}{2}^\circ - 4 \times 9,5 \times \sin 31\frac{1}{2}^\circ \\ - (14,8 + 19,4 + 23,9 + 28,1 + 32 + 35,5 + 38,7) \sin 31\frac{1}{2}^\circ$$

the solution being  $N (\text{max.}) = 54,3$ ,

which gives for  $y$ , forming with the force  $N$  an angle of  $52^\circ 35'$ ,

$$y (\text{max.}) = -\frac{54,3}{\cos 52^\circ 35'} = + 89,3 \text{ tons.}$$

$y$  (min.) will be defined when, with the exception of Apexes 3, 4, 5, 6, 7, 8 and 9, all the others are loaded.

Then, for the pressure at the vertex,

$$0 = H.50 + V.50 - 5595;$$

$$0 = -H.50 + V.50 + 5595 - 506 - 568 - 586 - 562 \\ - 509 - 430 - 337;$$

$$H = 77, \quad \text{and } V = 35;$$

206.] and from Fig. 206, for  $N$  (min.),

$$0 = N + 77 \cos 31\frac{1}{2}^\circ - 35 \sin 31\frac{1}{2}^\circ - 4 \times 9,5 \times \sin 31\frac{1}{2}^\circ \\ - (5 + 9,9) \sin 31\frac{1}{2}^\circ;$$

$$N (\text{min.}) = -19,7;$$

$$\text{therefore, for } y, \quad y = \frac{-19,7}{\cos 52^{\circ} 35'} = -32,5 \text{ tons.}$$

This may be sufficient to show the calculation of the single members, and we still want to show only the calculation of the strain,  $S$ , in the horizontal ring or band at the heels of the ribs.

207.] As in the case above described there are only a limited number of ribs, forming at their base a polygon (Fig. 207), which will also be the form of the ring, then

$$2 \sin 22\frac{1}{2}^{\circ} = H;$$

$$S = \frac{111,9}{2 \cdot 0,3827} = 146,1 \text{ tons.}$$

But when numerous ribs form the dome, so that the horizontal thrust toward the ring (as in Fig. 208) is equally distributed, 208.] and  $p$  the horizontal pressure per unit of length, then

$$p \times 2 r \varphi = 2 S \varphi, \quad \text{or } S = p \cdot r.$$

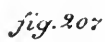
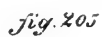
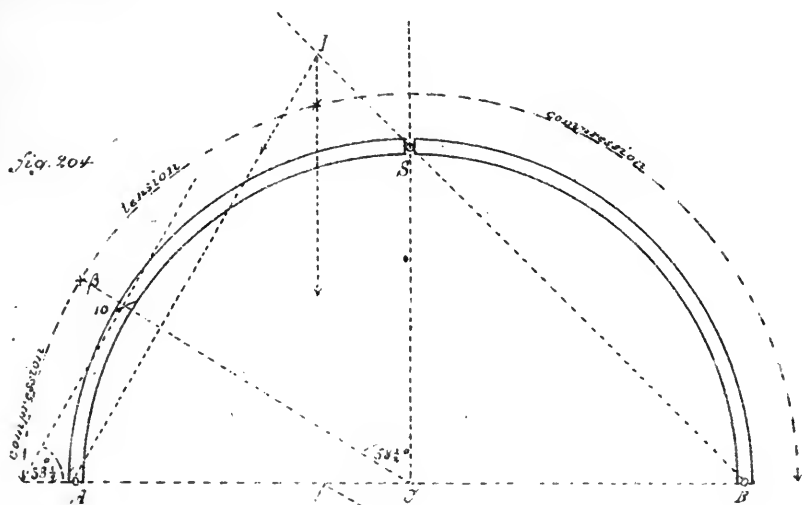
So for our example,

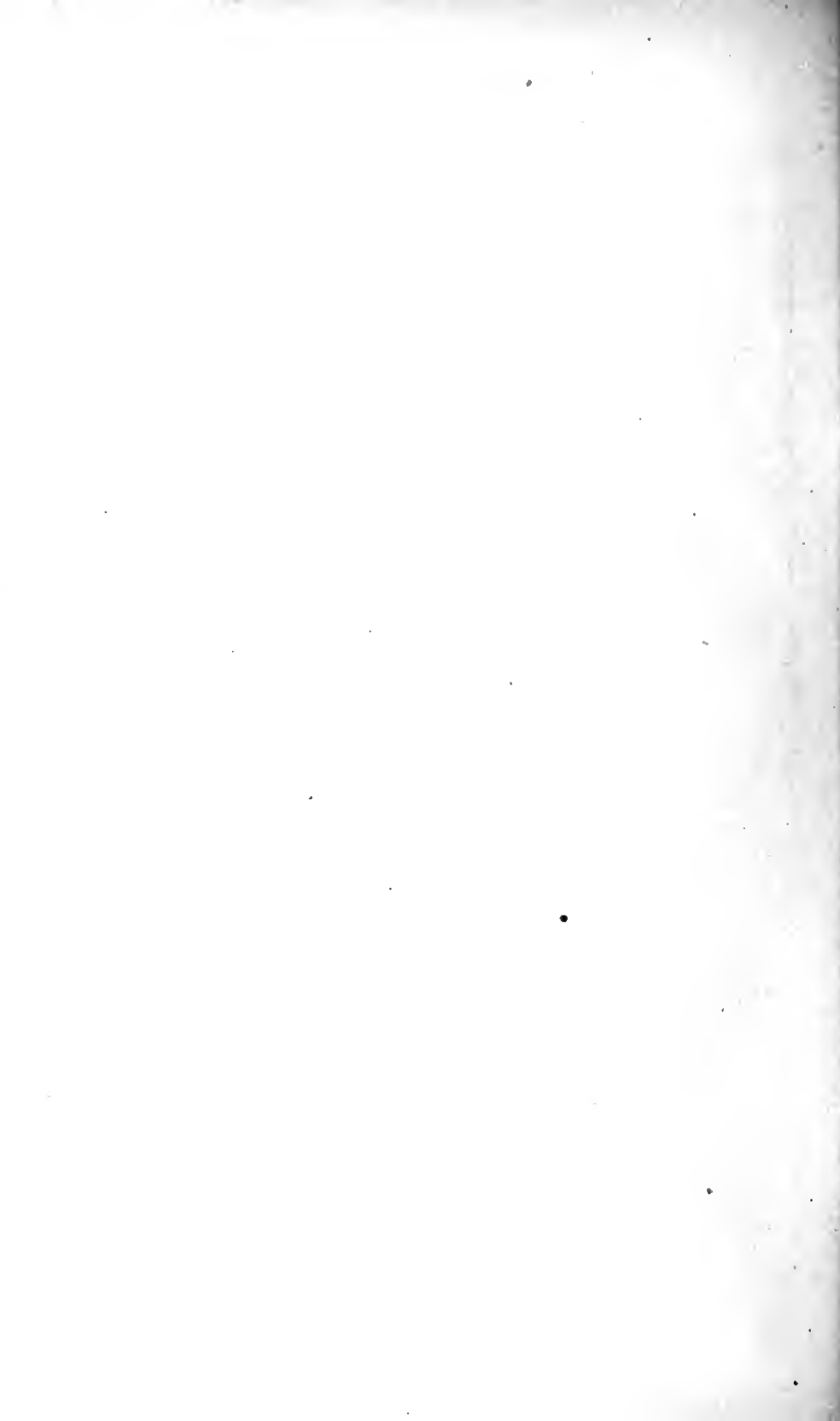
$$p = \frac{H}{r \cdot \frac{\pi}{4}} = \frac{111,9}{51 \times 0,785} = 2,794;$$

$$\text{and therefore } S = 2,794 \times 51 = 142,5 \text{ tons.}$$

[Plates 29, 30, 31, 32, 33 and 34—embracing Figs. 179 to 208.]

THE END.







# SCIENTIFIC BOOKS

PUBLISHED BY

## D. VAN NOSTRAND,

23 MURRAY STREET & 27 WARREN STREET,

NEW YORK.

---

### Weisbach's Mechanics.

*New and Revised Edition.*

8vo. Cloth. \$10.00.

A MANUAL OF THE MECHANICS OF ENGINEERING, and of the Construction of Machines. By JULIUS WEISBACH, PH. D. Translated from the fourth augmented and improved German edition, by ECKLEY B. COXE, A.M., Mining Engineer. Vol. I.—Theoretical Mechanics. 1,100 pages, and 902 wood-cut illustrations.

ABSTRACT OF CONTENTS.—Introduction to the Calculus—The General Principles of Mechanics—Phoronomics, or the Purely Mathematical Theory of Motion—Mechanics, or the General Physical Theory of Motion—Statics of Rigid Bodies—The Application of Statics to Elasticity and Strength—Dynamics of Rigid Bodies—Statics of Fluids—Dynamics of Fluids—The Theory of Oscillation, etc.

"The present edition is an entirely new work, greatly extended and very much improved. It forms a text-book which must find its way into the hands, not only of every student, but of every engineer who desires to refresh his memory or acquire clear ideas on doubtful points."—*Manufacturer and Builder*.

"We hope the day is not far distant when a thorough course of study and education as such shall be demanded of the practising engineer, and with this view we are glad to welcome this translation to our tongue and shores of one of the most able of the educators of Europe."—*The Technologist*.

## Francis' Lowell Hydraulics.

*Third Edition.*

4to. Cloth. \$15.00.

**LOWELL HYDRAULIC EXPERIMENTS** — being a Selection from Experiments on Hydraulic Motors, on the Flow of Water over Weirs, and in Open Canals of Uniform Rectangular Section, made at Lowell, Mass. By J. B. FRANCIS, Civil Engineer. Third edition, revised and enlarged, including many New Experiments on Gauging Water in Open Canals, and on the Flow through Submerged Orifices and Diverging Tubes. With 23 copperplates, beautifully engraved, and about 100 new pages of text.

The work is divided into parts. PART I., on hydraulic motors, includes ninety-two experiments on an improved Fourneyron Turbine Water-Wheel, of about two hundred horse-power, with rules and tables for the construction of similar motors; thirteen experiments on a model of a centre-vent water-wheel of the most simple design, and thirty-nine experiments on a centre-vent water-wheel of about two hundred and thirty horse-power.

PART II. includes seventy-four experiments made for the purpose of determining the form of the formula for computing the flow of water over weirs; nine experiments on the effect of back-water on the flow over weirs; eighty-eight experiments made for the purpose of determining the formula for computing the flow over weirs of regular or standard forms, with several tables of comparisons of the new formula with the results obtained by former experimenters; five experiments on the flow over a dam in which the crest was of the same form as that built by the Essex Company across the Merrimack River at Lawrence, Massachusetts; twenty-one experiments on the effect of observing the depths of water on a weir at different distances from the weir; an extensive series of experiments made for the purpose of determining rules for gauging streams of water in open canals, with tables for facilitating the same; and one hundred and one experiments on the discharge of water through submerged orifices and diverging tubes, the whole being fully illustrated by twenty-three double plates engraved on copper.

In 1855 the proprietors of the Locks and Canals on Merrimack River consented to the publication of the first edition of this work, which contained a selection of the most important hydraulic experiments made at Lowell up to that time. In this edition the principal hydraulic experiments made there, subsequent to 1855, have been added, including the important series above mentioned, for determining rules for the gauging the flow of water in open canals, and the interesting series on the flow through a submerged Venturi's tube, in which a larger flow was obtained than any we find recorded.

## Francis on Cast-Iron Pillars.

8vo. Cloth. \$2.00.

ON THE STRENGTH OF CAST-IRON PILLARS, with Tables for the use of Engineers, Architects, and Builders. By JAMES B. FRANCIS, Civil Engineer.

## Merrill's Iron Truss Bridges.

*Second Edition.*

4to. Cloth. \$5.00.

IRON TRUSS BRIDGES FOR RAILROADS. The Method of Calculating Strains in Trusses, with a careful comparison of the most prominent Trusses, in reference to economy in combination, etc., etc. By Brevet Colonel WILLIAM E. MERRILL, U.S.A., Major Corps of Engineers. Nine lithographed plates of illustrations.

"The work before us is an attempt to give a basis for sound reform in this feature of railroad engineering, by throwing 'additional light upon the method of calculating the maxima strains that can come upon any part of a bridge truss, and upon the manner of proportioning each part, so that it shall be as strong relatively to its own strains as any other part, and so that the entire bridge may be strong enough to sustain several times as great strains as the greatest that can come upon it in actual use.'"—*Scientific American*.

"The author has presented his views in a clear and intelligent manner, and the ingenuity displayed in coloring the figures so as to present certain facts to the eye forms no inappreciable part of the merits of the work. The reduction of the 'formule for obtaining the strength, volume, and weight of a cast-iron pillar under a strain of compression,' will be very acceptable to those who have occasion hereafter to make investigations involving these conditions. As a whole, the work has been well done."—*Railroad Gazette, Chicago*.

## Humber's Strains in Girders.

18mo. Cloth. \$2.50.

A HANDY BOOK FOR THE CALCULATION OF STRAINS IN GIRDERS and Similar Structures, and their Strength, consisting of Formulæ and Corresponding Diagrams, with numerous details for practical application. By WILLIAM HUMBER. Fully illustrated.

## Shreve on Bridges and Roofs.

8vo, 87 wood-cut illustrations. Cloth \$5.00.

A TREATISE ON THE STRENGTH OF BRIDGES AND ROOFS—comprising the determination of Algebraic formulas for Strains in Horizontal, Inclined or Rafter, Triangular, Bow-string, Lenticular and other Trusses, from fixed and moving loads, with practical applications and examples, for the use of Students and Engineers. By SAMUEL H. SHREVE, A.M., Civil Engineer.

"On the whole, Mr. Shreve has produced a book which is the simplest, clearest, and at the same time, the most systematic and with the best mathematical reasoning of any work upon the same subject in the language,"—*Railroad Gazette*.

"From the unusually clear language in which Mr. Shreve has given every statement, the student will have but himself to blame if he does not become thorough master of the subject."—*London Mining Journal*.

"Mr. Shreve has produced a work that must always take high rank as a text-book, \* \* \* and no Bridge Engineer should be without it, as a valuable work of reference, and one that will frequently assist him out of difficulties."—*Franklin Institute Journal*.

## The Kansas City Bridge.

4to. Cloth. \$6.00

WITH AN ACCOUNT OF THE REGIMEN OF THE MISSOURI RIVER, and a description of the Methods used for Founding in that River. By O. CHANUTE, Chief Engineer, and GEORGE MORISON, Assistant Engineer. Illustrated with five lithographic views and twelve plates of plans.

### Illustrations.

VIEWS.—View of the Kansas City Bridge, August 2, 1869. Lowering Caisson No. 1 into position. Caisson for Pier No. 4 brought into position. View of Foundation Works, Pier No. 4. Pier No. 1.

PLATES.—I. Map showing location of Bridge. II. Water Record—Cross Section of River—Profile of Crossing—Pontoon Protection. III. Water Deadener—Caisson No. 2—Founda-

tion Works, Pier No. 3. IV. Foundation Works, Pier No. 4. V. Foundation Works, Pier No. 4. VI. Caisson No. 5—Sheet Piling at Pier No. 6—Details of Dredges—Pile Shoe—Beton Box. VII. Masonry—Draw Protection—False Works between Piers 3 and 4. VIII. Floating Derricks. IX. General Elevation—176 feet span. X. 248 feet span. XI. Plans of Draw. XII. Strain Diagrams.

## Clarke's Quincy Bridge.

4to. Cloth. \$7.50.

DESCRIPTION OF THE IRON RAILWAY Bridge across the Mississippi River at Quincy, Illinois. By THOMAS CURTIS CLARKE, Chief Engineer. Illustrated with twenty-one lithographed plans.

### *Illustrations.*

PLATES.—General Plan of Mississippi River at Quincy, showing location of Bridge. IIa. General Sections of Mississippi River at Quincy, showing location of Bridge. IIb. General Sections of Mississippi River at Quincy, showing location of Bridge. III. General Sections of Mississippi River at Quincy, showing location of Bridge. IV. Plans of Masonry. V. Diagram of Spans, showing the Dimensions, Arrangement of Panels, etc. VI. Two hundred and fifty feet span, and details. VII. Three hundred and sixty feet Pivot Draw. VIII. Details of three hundred and sixty feet Draw. IX. Ice-Breakers, Foundations of Piers and Abutments, Water Table, and

Curve of Deflections. X. Foundations of Pier 2, in Process of Construction. XI. Foundations of Pier 3, and its Protection. XII. Foundations of Pier 3, in Process of Construction, and Steam Dredge. XIII. Foundations of Piers 5 to 18, in Process of Construction. XIV. False Works, showing Process of Handling and Setting Stone. XV. False Works for Raising Iron Work of Superstructure. XVI. Steam Dredge used in Foundations 9 to 18. XVII. Single Bucket Dredge used in Foundations of Bay Piers. XVIII. Saws used for Cutting Piles under water. XIX. Sand Pump and Concrete Box. XX. Masonry Travelling Crane.

## Whipple on Bridge Building.

8vo, Illustrated. Cloth. \$4.00.

AN ELEMENTARY AND PRACTICAL TREATISE ON BRIDGE BUILDING. An enlarged and improved edition of the Author's original work. By S. WHIPPLE, C. E., Inventor of the Whipple Bridges, &c. Second Edition.

The design has been to develop from Fundamental Principles a system easy of comprehension, and such as to enable the attentive reader and student to judge understandingly for himself, as to the relative merits of different plans and combinations, and to adopt for use such as may be most suitable for the cases he may have to deal with.

It is hoped the work may prove an appropriate Text-Book upon the subject treated of, for the Engineering Student, and a useful manual for the Practicing Engineer and Bridge Builder.

## Stoney on Strains.

*New and Revised Edition, with numerous illustrations.*

Royal 8vo, 664 pp. Cloth. \$12.50.

THE THEORY OF STRAINS IN GIRDERS and Similar Structures, with Observations on the Application of Theory to Practice, and Tables of Strength and other Properties of Materials. By BINDON B. STONEY, B. A.

## Roebeling's Bridges.

Imperial folio. Cloth. \$25.00.

LONG AND SHORT SPAN RAILWAY BRIDGES. By JOHN A. ROEBLING, C. E. Illustrated with large copperplate engravings of plans and views.

### *List of Plates*

1. Parabolic Truss Railway Bridge. 2, 3, 4, 5, 6. Details of Parabolic Truss, with centre span 500 feet in the clear. 7. Plan and View of a Bridge over the Mississippi River, at St. Louis, for railway and common travel. 8, 9, 10, 11, 12. Details and View of St. Louis Bridge. 13. Railroad Bridge over the Ohio.

## Diedrichs' Theory of Strains.

8vo. Cloth. \$5.00.

A Compendium for the Calculation and Construction of Bridges, Roofs, and Cranes, with the Application of Trigonometrical Notes. Containing the most comprehensive information in regard to the Resulting Strains for a permanent Load, as also for a combined (Permanent and Rolling) Load. In two sections adapted to the requirements of the present time. By JOHN DIEDRICHS. Illustrated by numerous plates and diagrams.

"The want of a compact, universal and popular treatise on the Construction of Roofs and Bridges—especially one treating of the influence of a variable load—and the unsatisfactory essays of different authors on the subject, induced me to prepare this work."

## Whilden's Strength of Materials.

12mo. Cloth. \$2.00.

ON THE STRENGTH OF MATERIALS used in Engineering Construction. By J. K. WHILDEN.

## Campin on Iron Roofs.

Large 8vo. Cloth. \$2.00.

ON THE CONSTRUCTION OF IRON ROOFS. A Theoretical and Practical Treatise. By FRANCIS CAMPIN. With wood-cuts and plates of Roofs lately executed.

"The mathematical formulas are of an elementary kind, and the process admits of an easy extension so as to embrace the prominent varieties of iron truss bridges. The treatise, though of a practical scientific character, may be easily mastered by any one familiar with elementary mechanics and plane trigonometry."

## Holley's Railway Practice.

1 vol. folio. Cloth. \$12.00.

AMERICAN AND EUROPEAN RAILWAY PRACTICE, in the Economical Generation of Steam, including the materials and construction of Coal-burning Boilers, Combustion, the Variable Blast, Vaporization, Circulation, Super-heating, Supplying and Heating Feed-water, &c., and the adaptation of Wood and Coke-burning Engines to Coal-burning; and in Permanent Way, including Road-bed, Sleepers, Rails, Joint Fastenings, Street Railways, &c., &c. By ALEXANDER L. HOLLEY, B. P. With 77 lithographed plates.

"This is an elaborate treatise by one of our ablest civil engineers, on the construction and use of locomotives, with a few chapters on the building of Railroads. \* \* \* All these subjects are treated by the author, who is a first-class railroad engineer, in both an intelligent and intelligible manner. The facts and ideas are well arranged, and presented in a clear and simple style, accompanied by beautiful engravings, and we presume the work will be regarded as indispensable by all who are interested in a knowledge of the construction of railroads and rolling stock, or the working of locomotives."—*Scientific American*.

## Henrici's Skeleton Structures.

8vo. Cloth. \$1.50.

SKELETON STRUCTURES, especially in their Application to the building of Steel and Iron Bridges. By OLAVS HENRICI. With folding plates and diagrams.

By presenting these general examinations on Skeleton Structures, with particular application for Suspended Bridges, to Engineers, I venture to express the hope that they will receive these theoretical results with some confidence, even although an opportunity is wanting to compare them with practical results.

O. H.

---

## Useful Information for Railway Men.

Pocket form. Morocco, gilt, \$2.00.

Compiled by W. G. HAMILTON, Engineer. Fifth edition, revised and enlarged. 570 pages.

"It embodies many valuable formulæ and recipes useful for railway men, and, indeed, for almost every class of persons in the world. The 'information' comprises some valuable formulæ and rules for the construction of boilers and engines, masonry, properties of steel and iron, and the strength of materials generally."—*Railroad Gazette, Chicago.*

---

## Brooklyn Water Works.

1 vol. folio. Cloth. \$25.00.

A DESCRIPTIVE ACCOUNT OF THE CONSTRUCTION OF THE WORKS, and also Reports on the Brooklyn, Hartford, Belleville, and Cambridge Pumping Engines. Prepared and printed by order of the Board of Water Commissioners. With 59 illustrations.

CONTENTS.—Supply Ponds—The Conduit—Ridgewood Engine House and Pump Well—Ridgewood Engines—Force Mains—Ridgewood Reservoir—Pipe Distribution—Mount Prospect Reservoir—Mount Prospect Engine House and Engine—Drainage Grounds—Sewerage Works—Appendix.



## Kirkwood on Filtration.

4to. Cloth. \$15.00.

REPORT ON THE FILTRATION OF RIVER WATERS, for the Supply of Cities, as practised in Europe, made to the Board of Water Commissioners of the City of St. Louis. By JAMES P. KIRKWOOD. Illustrated by 30 double-plate engravings.

CONTENTS.—Report on Filtration—London Works, General—Chelsea Water Works and Filters—Lambeth Water Works and Filters—Southwark and Vauxhall Water Works and Filters—Grand Junction Water Works and Filters—West Middlesex Water Works and Filters—New River Water Works and Filters—East London Water Works and Filters—Leicester Water Works and Filters—York Water Works and Filters—Liverpool Water Works and Filters—Edinburgh Water Works and Filters—Dublin Water Works and Filters—Perth Water Works and Filtering Gallery—Berlin Water Works and Filters—Hamburg Water Works and Reservoirs—Altona Water Works and Filters—Tours Water Works and Filtering Canal—Angers Water Works and Filtering Galleries—Nantes Water Works and Filters—Lyons Water Works and Filtering Galleries—Toulouse Water Works and Filtering Galleries—Marseilles Water Works and Filters—Genoa Water Works and Filtering Galleries—Leghorn Water Works and Cisterns—Wakefield Water Works and Filters—Appendix.

---

## Tunner on Roll-Turning.

1 vol. 8vo. and 1 vol. plates. \$10.00.

A TREATISE ON ROLL-TURNING FOR THE MANUFACTURE OF IRON. By PETER TUNNER. Translated and adapted. By JOHN B. PEARSE, of the Pennsylvania Steel Works. With numerous wood-cuts, 8vo., together with a folio atlas of 10 lithographed plates of Rolls, Measurements, &c.

“We commend this book as a clear, elaborate, and practical treatise upon the department of iron manufacturing operations to which it is devoted. The writer states in his preface, that for twenty-five years he has felt the necessity of such a work, and has evidently brought to its preparation the fruits of experience, a painstaking regard for accuracy of statement, and a desire to furnish information in a style readily understood. The book should be in the hands of every one interested, either in the general practice of mechanical engineering, or the special branch of manufacturing operations to which the work relates.”—*American Artisan*.

## Glynn on the Power of Water.

12mo. Cloth. \$1.00.

A TREATISE ON THE POWER OF WATER, as applied to drive Flour Mills, and to give motion to Turbines and other Hydrostatic Engines. By JOSEPH GLYNN, F.R. S. Third edition, revised and enlarged, with numerous illustrations.

---

## Hewson on Embankments.

8vo. Cloth. \$2.00.

PRINCIPLES AND PRACTICE OF EMBANKING LANDS from River Floods, as applied to the Levees of the Mississippi. By WILLIAM HEWSON, Civil Engineer.

"This is a valuable treatise on the principles and practice of embanking lands from river floods, as applied to the Levees of the Mississippi, by a highly intelligent and experienced engineer. The author says it is a first attempt to reduce to order and to rule the design, execution, and measurement of the Levees of the Mississippi. It is a most useful and needed contribution to scientific literature.—*Philadelphia Evening Journal*.

---

## Grüner on Steel.

8vo. Cloth. \$3.50.

THE MANUFACTURE OF STEEL. By M. L. GRÜNER, translated from the French. By Lenox Smjth, A. M., E. M., with an appendix on the Bessemer Process in the United States, by the translator. Illustrated by lithographed drawings and wood-cuts.

"The purpose of the work is to present a careful, elaborate, and at the same time practical examination into the physical properties of steel, as well as a description of the new processes and mechanical appliances for its manufacture. The information which it contains, gathered from many trustworthy sources, will be found of much value to the American steel manufacturer, who may thus acquaint himself with the results of careful and elaborate experiments in other countries, and better prepare himself for successful competition in this important industry with foreign makers. The fact that this volume is from the pen of one of the ablest metallurgists of the present day, cannot fail, we think, to secure for it a favorable consideration.—*Iron Age*.

## Bauerman on Iron.

12mo. Cloth. \$2.00.

TREATISE ON THE METALLURGY OF IRON. Containing outlines of the History of Iron Manufacture, methods of Assay, and analysis of Iron Ores, processes of manufacture of Iron and Steel, etc., etc. By H. BAUERMAN. First American edition. Revised and enlarged, with an appendix on the Martin Process for making Steel, from the report of Abram S. Hewitt. Illustrated with numerous wood engravings.

"This is an important addition to the stock of technical works published in this country. It embodies the latest facts, discoveries, and processes connected with the manufacture of iron and steel, and should be in the hands of every person interested in the subject, as well as in all technical and scientific libraries."—*Scientific American*.

---

## Link and Valve Motions, by W. S. Auchincloss.

8vo. Cloth. \$3.00.

APPLICATION OF THE SLIDE VALVE and Link Motion to Stationary, Portable, Locomotive and Marine Engines, with new and simple methods for proportioning the parts. By WILLIAM S. AUCHINCLOSS, Civil and Mechanical Engineer. Designed as a hand-book for Mechanical Engineers, Master Mechanics, Draughtsmen and Students of Steam Engineering. All dimensions of the valve are found with the greatest ease by means of a Printed Scale, and proportions of the link determined *without* the assistance of a model. Illustrated by 37 wood-cuts and 21 lithographic plates, together with a copperplate engraving of the Travel Scale.

All the matters we have mentioned are treated with a clearness and absence of unnecessary verbiage which renders the work a peculiarly valuable one. The Travel Scale only requires to be known to be appreciated. Mr. A. writes so ably on his subject, we wish he had written more. *London Engineering*.

We have never opened a work relating to steam which seemed to us better calculated to give an intelligent mind a clear understanding of the department it discusses.—*Scientific American*.

## Slide Valve by Eccentrics, by Prof. C. W. MacCord.

4to. Illustrated. Cloth, \$4.00.

A PRACTICAL TREATISE ON THE SLIDE VALVE BY ECCENTRICS, examining by methods, the action of the Eccentric upon the Slide Valve, and explaining the practical processes of laying out the movements, adapting the valve for its various duties in the steam-engine. For the use of Engineers, Draughtsmen, Machinists, and Students of valve motions in general. By C. W. MacCord, A. M., Professor of Mechanical Drawing, Stevens' Institute of Technology, Hoboken, N J.

## Stillman's Steam-Engine Indicator.

12mo. Cloth. \$1.00.

THE STEAM-ENGINE INDICATOR, and the Improved Manometer Steam and Vacuum Gauges; their utility and application By PAUL STILLMAN. New edition.

## Bacon's Steam-Engine Indicator.

12mo. Cloth. \$1.00. Mor. \$1.50.

A TREATISE ON THE RICHARDS STEAM-ENGINE INDICATOR, with directions for its use. By CHARLES T. PORTER. Revised, with notes and large additions as developed by American Practice, with an Appendix containing useful formulæ and rules for Engineers. By F. W. BACON, M. E., Member of the American Society of Civil Engineers. Illustrated. Second Edition

In this work, Mr. Porter's book has been taken as the basis, but Mr. Bacon has adapted it to American Practice, and has conferred a great boon on American Engineers.—*Artisan*.

## Bartol on Marine Boilers.

8vo. Cloth. \$1.50.

TREATISE ON THE MARINE BOILERS OF THE UNITED STATES. By H. B. BARTOL. Illustrated.

## Gillmore's Limes and Cements.

*Fourth Edition. Revised and Enlarged.*

8vo. Cloth. \$4.00.

PRACTICAL TREATISE ON LIMES, HYDRAULIC CEMENTS, AND MORTARS. Papers on Practical Engineering, U. S. Engineer Department, No. 9, containing Reports of numerous experiments conducted in New York City, during the years 1858 to 1861, inclusive. By Q. A. GILLMORE, Brig-General U. S. Volunteers, and Major U. S. Corps of Engineers. With numerous illustrations.

"This work contains a record of certain experiments and researches made under the authority of the Engineer Bureau of the War Department from 1858 to 1861, upon the various hydraulic cements of the United States, and the materials for their manufacture. The experiments were carefully made, and are well reported and compiled."—*Journal Franklin Institute.*

---

## Gillmore's Coignet Beton.

8vo. Cloth. \$2.50.

COIGNET BETON AND OTHER ARTIFICIAL STONE. By Q. A. GILLMORE. 9 Plates, Views, etc.

This work describes with considerable minuteness of detail the several kinds of artificial stone in most general use in Europe and now beginning to be introduced in the United States, discusses their properties, relative merits, and cost, and describes the materials of which they are composed. . . . The subject is one of special and growing interest, and we commend the work, embodying as it does the matured opinions of an experienced engineer and expert.

---

## Williamson's Practical Tables.

4to. Flexible Cloth. \$2.50.

PRACTICAL TABLES IN METEOROLOGY AND HYPSONOMETRY, in connection with the use of the Barometer. By Col. R. S. WILLIAMSON, U. S. A.

## Williamson on the Barometer.

4to. Cloth. \$15.00.

ON THE USE OF THE BAROMETER ON SURVEYS AND RECONNAISSANCES. Part I. Meteorology in its Connection with Hypsometry. Part II. Barometric Hypsometry. By R. S. WILLIAMSON, Bvt. Lieut.-Col. U. S. A., Major Corps of Engineers. With Illustrative Tables and Engravings. Paper No. 15, Professional Papers, Corps of Engineers.

"SAN FRANCISCO, CAL., Feb. 27, 1867.

"Gen. A. A. HUMPHREYS, Chief of Engineers, U. S. Army :

"GENERAL,—I have the honor to submit to you, in the following pages, the results of my investigations in meteorology and hypsometry, made with the view of ascertaining how far the barometer can be used as a reliable instrument for determining altitudes on extended lines of survey and reconnaissances. These investigations have occupied the leisure permitted me from my professional duties during the last ten years, and I hope the results will be deemed of sufficient value to have a place assigned them among the printed professional papers of the United States Corps of Engineers.

"Very respectfully, your obedient servant,

"R. S. WILLIAMSON,

"Bvt. Lt.-Col. U. S. A., Major Corps of U. S. Engineers."

## Von Cotta's Ore Deposits.

8vo. Cloth. \$4.00.

TREATISE ON ORE DEPOSITS. By BERNHARD VON COTTA, Professor of Geology in the Royal School of Mines, Freiberg, Saxony. Translated from the second German edition, by FREDERICK PRIME, Jr., Mining Engineer, and revised by the author, with numerous illustrations.

"Prof. Von Cotta of the Freiberg School of Mines, is the author of the best modern treatise on ore deposits, and we are heartily glad that this admirable work has been translated and published in this country. The translator, Mr. Frederick Prime, Jr., a graduate of Freiberg, has had in his work the great advantage of a revision by the author himself, who declares in a prefatory note that this may be considered as a new edition (the third, of his own book.

"It is a timely and welcome contribution to the literature of mining in this country, and we are grateful to the translator for his enterprise and good judgment in undertaking its preparation; while we recognize with equal cordiality the liberality of the author in granting both permission and assistance."—*Extract from Review in Engineering and Mining Journal.*

## Plattner's Blow-Pipe Analysis.

Second edition. Revised. 8vo. Cloth. \$7.50.

PLATTNER'S MANUAL OF QUALITATIVE AND QUANTITATIVE ANALYSIS WITH THE BLOW-PIPE. From the last German edition Revised and enlarged. By Prof. TH. RICHTER, of the Royal Saxon Mining Academy. Translated by Prof. H. B. CORNWALL, Assistant in the Columbia School of Mines, New York; assisted by JOHN H. CASWELL. Illustrated with eighty-seven wood-cuts and one Lithographic Plate. 560 pages.

"Plattner's celebrated work has long been recognized as the only complete book on Blow-Pipe Analysis. The fourth German edition, edited by Prof. Richter, fully sustains the reputation which the earlier editions acquired during the lifetime of the author, and it is a source of great satisfaction to us to know that Prof. Richter has co-operated with the translator in issuing the American edition of the work, which is in fact a fifth edition of the original work, being far more complete than the last German edition."—*Silliman's Journal*.

There is nothing so complete to be found in the English language. Plattner's book is not a mere pocket edition; it is intended as a comprehensive guide to all that is at present known on the blow-pipe, and as such is really indispensable to teachers and advanced pupils.

"Mr. Cornwall's edition is something more than a translation, as it contains many corrections, emendations and additions not to be found in the original. It is a decided improvement on the work in its German dress."—*Journal of Applied Chemistry*.

---

## Egleston's Mineralogy.

8vo. Illustrated with 34 Lithographic Plates. Cloth. \$4.50.

LECTURES ON DESCRIPTIVE MINERALOGY, Delivered at the School of Mines, Columbia College. By PROFESSOR T. EGLESTON.

These lectures are what their title indicates, the lectures on Mineralogy delivered at the School of Mines of Columbia College. They have been printed for the students, in order that more time might be given to the various methods of examining and determining minerals. The second part has only been printed. The first part, comprising crystallography and physical mineralogy, will be printed at some future time.

## Pynchon's Chemical Physics.

*New Edition. Revised and Enlarged.*

Crown 8vo. Cloth. \$3.00.

INTRODUCTION TO CHEMICAL PHYSICS, Designed for the Use of Academies, Colleges, and High Schools. Illustrated with numerous engravings, and containing copious experiments with directions for preparing them. By THOMAS RUGGLES PYNCHON, M.A., Professor of Chemistry and the Natural Sciences, Trinity College, Hartford.

Hitherto, no work suitable for general use, treating of all these subjects within the limits of a single volume, could be found; consequently the attention they have received has not been at all proportionate to their importance. It is believed that a book containing so much valuable information within so small a compass, cannot fail to meet with a ready sale among all intelligent persons, while Professional men, Physicians, Medical Students, Photographers, Telegraphers, Engineers, and Artisans generally, will find it specially valuable, if not nearly indispensable, as a book of reference.

"We strongly recommend this able treatise to our readers as the first work ever published on the subject free from perplexing technicalities. In style it is pure, in description graphic, and its typographical appearance is artistic. It is altogether a most excellent work."—*Eclectic Medical Journal*.

"It treats fully of Photography, Telegraphy, Steam Engines, and the various applications of Electricity. In short, it is a carefully prepared volume, abreast with the latest scientific discoveries and inventions."—*Hartford Courant*.

## Plympton's Blow-Pipe Analysis.

12mo. Cloth. \$2.00.

THE BLOW-PIPE: A System of Instruction in its practical use being a graduated course of Analysis for the use of students, and all those engaged in the Examination of Metallic Combinations. Second edition, with an appendix and a copious index. By GEORGE W. PLYMPTON, of the Polytechnic Institute, Brooklyn.

"This manual probably has no superior in the English language as a textbook for beginners, or as a guide to the student working without a teacher. To the latter many illustrations of the utensils and apparatus required in using the blow-pipe, as well as the fully illustrated description of the blow-pipe flame, will be especially serviceable."—*New York Teacher*.



**Ure's Dictionary.***Sixth Edition.*

London, 1872.

3 vols. 8vo. Cloth, \$25.00. Half Russia, \$32.50.

**DICTIONARY OF ARTS, MANUFACTURES, AND MINES.**

By ANDREW URE, M.D. Sixth edition. Edited by ROBERT HUNT, F.R.S., greatly enlarged and rewritten.

**Brande and Cox's Dictionary.***New Edition.*

London, 1872.

3 vols. 8vo. Cloth, \$20.00. Half Morocco, \$27.50.

**A Dictionary of Science, Literature, and Art.** Edited by W. T.

BRANDE and Rev. GEO. W. COX. New and enlarged edition.

**Watt's Dictionary of Chemistry.***Supplementary Volume.*

8vo. Cloth. \$9.00.

This volume brings the Record of Chemical Discovery down to the end of the year 1869, including also several additions to, and corrections of, former results which have appeared in 1870 and 1871.

\* \* Complete Sets of the Work, New and Revised edition, including above supplement. 6 vols. 8vo. Cloth. \$62.00.

**Rammelsberg's Chemical Analysis.**

8vo. Cloth. \$2.25.

**GUIDE TO A COURSE OF QUANTITATIVE CHEMICAL ANALYSIS, ESPECIALLY OF MINERALS AND FURNACE PRODUCTS.** Illustrated by Examples. By C. F. RAMMELSBERG. Translated by J. TOWLER, M.D.

This work has been translated, and is now published expressly for those students in chemistry whose time and other studies in colleges do not permit them to enter upon the more elaborate and expensive treatises of Fresenius and others. It is the condensed labor of a master in chemistry and of a practical analyst.

## Eliot and Storer's Qualitative Chemical Analysis.

*New Edition, Revised.*

12mo. Illustrated. Cloth. \$1.50.

A COMPENDIOUS MANUAL OF QUALITATIVE CHEMICAL ANALYSIS. By CHARLES W. ELIOT and FRANK H. STORER. Revised with the Coöperation of the Authors, by WILLIAM RIPLEY NICHOLS, Professor of Chemistry in the Massachusetts Institute of Technology.

"This Manual has great merits as a practical introduction to the science and the art of which it treats. It contains enough of the theory and practice of qualitative analysis, "in the wet way," to bring out all the reasoning involved in the science, and to present clearly to the student the most approved methods of the art. It is specially adapted for exercises and experiments in the laboratory; and yet its classifications and manner of treatment are so systematic and logical throughout, as to adapt it in a high degree to that higher class of students generally who desire an accurate knowledge of the practical methods of arriving at scientific facts."—*Lutheran Observer*.

"We wish every academical class in the land could have the benefit of the fifty exercises of two hours each necessary to master this book. Chemistry would cease to be a mere matter of memory, and become a pleasant experimental and intellectual recreation. We heartily commend this little volume to the notice of those teachers who believe in using the sciences as means of mental discipline."—*College Courant*.

## Craig's Decimal System.

Square 32mo. Limp. 50c.

WEIGHTS AND MEASURES. An Account of the Decimal System, with Tables of Conversion for Commercial and Scientific Uses. By B. F. CRAIG, M. D.

"The most lucid, accurate, and useful of all the hand-books on this subject that we have yet seen. It gives forty-seven tables of comparison between the English and French denominations of length, area, capacity, weight, and the Centigrade and Fahrenheit thermometers, with clear instructions how to use them; and to this practical portion, which helps to make the transition as easy as possible, is prefixed a scientific explanation of the errors in the metric system, and how they may be corrected in the laboratory."—*Nation*.

## Nugent on Optics.

12mo. Cloth. \$2.00

TREATISE ON OPTICS; or, Light and Sight, theoretically and practically treated; with the application to Fine Art and Industrial Pursuits. By E. NUGENT. With one hundred and three illustrations.

"This book is of a practical rather than a theoretical kind, and is designed to afford accurate and complete information to all interested in applications of the science."—*Round Table*.

---

## Barnard's Metric System.

8vo. Brown cloth. \$3.00.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

An Address delivered before the Convocation of the University of the State of New York, at Albany, August, 1871. By FREDERICK A. P. BARNARD, President of Columbia College, New York City. Second edition from the Revised edition printed for the Trustees of Columbia College. Tinted paper.

"It is the best summary of the arguments in favor of the metric weights and measures with which we are acquainted, not only because it contains in small space the leading facts of the case, but because it puts the advocacy of that system on the only tenable grounds, namely, the great convenience of a decimal notation of weight and measure as well as money, the value of international uniformity in the matter, and the fact that this metric system is adopted and in general use by the majority of civilized nations."—*The Nation*.

---

## The Young Mechanic.

Illustrated. 12mo. Cloth. \$1.75.

THE YOUNG MECHANIC. Containing directions for the use of all kinds of tools, and for the construction of steam engines and mechanical models, including the Art of Turning in Wood and Metal. By the author of "The Lathe and its Uses," etc From the English edition, with corrections.

## Harrison's Mechanic's Tool-Book.

12mo. Cloth. \$1.50.

MECHANIC'S TOOL BOOK, with practical rules and suggestions, for the use of Machinists, Iron Workers, and others. By W. B. HARRISON, Associate Editor of the "American Artisan." Illustrated with 44 engravings.

"This work is specially adapted to meet the wants of Machinists and workers in iron generally. It is made up of the work-day experience of an intelligent and ingenious mechanic, who had the faculty of adapting tools to various purposes. The practicability of his plans and suggestions are made apparent even to the unpractised eye by a series of well-executed wood engravings." — *Philadelphia Inquirer*.

## Pope's Modern Practice of the Electric Telegraph.

Eighth Edition. 8vo. Cloth. \$2.00.

A Hand-book for Electricians and Operators. By FRANK L. POPE. Seventh edition. Revised and enlarged, and fully illustrated.

*Extract from Letter of Prof. Morse.*

"I have had time only cursorily to examine its contents, but this examination has resulted in great gratification, especially at the fairness and unprejudiced tone of your whole work.

"Your illustrated diagrams are admirable and beautifully executed.

"I think all your instructions in the use of the telegraph apparatus judicious and correct, and I most cordially wish you success."

*Extract from Letter of Prof. G. W. Hough, of the Dudley Observatory.*

"There is no other work of this kind in the English language that contains in so small a compass so much practical information in the application of galvanic electricity to telegraphy. It should be in the hands of every one interested in telegraphy, or the use of Batteries for other purposes."

## Morse's Telegraphic Apparatus.

Illustrated. 8vo. Cloth. \$2.00.

EXAMINATION OF THE TELEGRAPHIC APPARATUS AND THE PROCESSES IN TELEGRAPHY. By SAMUEL F. B. MORSE, LL.D., United States Commissioner Paris Universal Exposition, 1867.

## Sabine's History of the Telegraph.

12mo. Cloth. \$1.25.

**HISTORY AND PROGRESS OF THE ELECTRIC TELEGRAPH**, with Descriptions of some of the Apparatus. By ROBERT SABINE, C. E. Second edition, with additions.

**CONTENTS.**—I. Early Observations of Electrical Phenomena. II. Telegraphs by Frictional Electricity. III. Telegraphs by Voltaic Electricity. IV. Telegraphs by Electro-Magnetism and Magneto-Electricity. V. Telegraphs now in use. VI. Overhead Lines. VII. Submarine Telegraph Lines. VIII. Underground Telegraphs. IX. Atmospheric Electricity.

## Haskins' Galvanometer.

Pocket form. Illustrated. Morocco tucks. \$2.00.

**THE GALVANOMETER, AND ITS USES**; a Manual for Electricians and Students. By C. H. HASKINS.

"We hope this excellent little work will meet with the sale its merits entitle it to. To every telegrapher who owns, or uses a Galvanometer, or ever expects to, it will be quite indispensable."—*The Telegrapher*.

## Culley's Hand-Book of Telegraphy.

8vo. Cloth. \$6.00.

**A HAND-BOOK OF PRACTICAL TELEGRAPHY.** By R. S. CULLEY, Engineer to the Electric and International Telegraph Company. Fifth edition, revised and enlarged.

## Foster's Submarine Blasting.

4to. Cloth. \$3.50.

**SUBMARINE BLASTING** in Boston Harbor, Massachusetts—Removal of Tower and Corwin Rocks. By JOHN G. FOSTER, Lieutenant-Colonel of Engineers, and Brevet Major-General, U. S. Army. Illustrated with seven plates.

**LIST OF PLATES.**—1. Sketch of the Narrows, Boston Harbor. 2. Townsend's Submarine Drilling Machine, and Working Vessel attending. 3. Submarine Drilling Machine employed. 4. Details of Drilling Machine employed. 5. Cartridges and Tamping used. 6. Fuses and Insulated Wires used. 7. Portable Friction Battery used.

## Barnes' Submarine Warfare.

8vo. Cloth. \$5.00.

### SUBMARINE WARFARE, DEFENSIVE AND OFFENSIVE.

Comprising a full and complete History of the Invention of the Torpedo, its employment in War and results of its use. Descriptions of the various forms of Torpedoes, Submarine Batteries and Torpedo Boats actually used in War. Methods of Ignition by Machinery, Contact Fuzes, and Electricity, and a full account of experiments made to determine the Explosive Force of Gunpowder under Water. Also a discussion of the Offensive Torpedo system, its effect upon Iron-Clad Ship systems, and influence upon Future Naval Wars. By Lieut.-Commander JOHN S. BARNES, U. S. N. With twenty lithographic plates and many wood-cuts.

"A book important to military men, and especially so to engineers and artillerymen. It consists of an examination of the various offensive and defensive engines that have been contrived for submarine hostilities, including a discussion of the torpedo system, its effects upon iron-clad ship-systems, and its probable influence upon future naval wars. Plates of a valuable character accompany the treatise, which affords a useful history of the momentous subject it discusses. A great deal of useful information is collected in its pages, especially concerning the inventions of SCHOLL and VERDU, and of JONES' and HUNT's batteries, as well as of other similar machines, and the use in submarine operations of gun-cotton and nitro-glycerine."—*N. Y. Times*.

## Randall's Quartz Operator's Hand-Book.

12mo. Cloth. \$2.00.

### QUARTZ OPERATOR'S HAND-BOOK. By P. M. RANDALL.

New edition, revised and enlarged. Fully illustrated.

The object of this work has been to present a clear and comprehensive exposition of mineral veins, and the means and modes chiefly employed for the mining and working of their ores—more especially those containing gold and silver.

## Mitchell's Manual of Assaying.

8vo. Cloth. \$10.00.

A MANUAL OF PRACTICAL ASSAYING. By JOHN MITCHELL.  
Third edition. Edited by WILLIAM CROOKES, F.R.S.

In this edition are incorporated all the late important discoveries in Assaying made in this country and abroad, and special care is devoted to the very important Volumetric and Colorimetric Assays, as well as to the Blow-Pipe Assays.

---

## Benét's Chronoscope.

*Second Edition.*

Illustrated. 4to. Cloth. \$3.00.

ELECTRO-BALLISTIC MACHINES, and the Schultz Chronoscope. By Lieutenant-Colonel S. V. BENÉT, Captain of Ordnance, U. S. Army.

CONTENTS.—1. Ballistic Pendulum. 2. Gun Pendulum. 3. Use of Electricity. 4. Navez' Machine. 5. Vignotti's Machine, with Plates. 6. Benton's Electro-Ballistic Pendulum, with Plates. 7. Leur's Tro-Pendulum Machine. 8. Schultz's Chronoscope, with two Plates.

---

## Michaelis' Chronograph.

4to. Illustrated. Cloth. \$3.00.

THE LE BOULENGÉ CHRONOGRAPH. With three lithographed folding plates of illustrations. By Brevet Captain O E. MICHAELIS, First Lieutenant Ordnance Corps, U. S. Army.

"The excellent monograph of Captain Michaelis enters minutely into the details of construction and management, and gives tables of the times of flight calculated upon a given fall of the chronometer for all distances. Captain Michaelis has done good service in presenting this work to his brother officers, describing, as it does, an instrument which bids fair to be in constant use in our future ballistic experiments."—*Army and Navy Journal*.

## Silversmith's Hand-Book.

*Fourth Edition.*

Illustrated. 12mo. Cloth. \$3.00.

A PRACTICAL HAND-BOOK FOR MINERS, Metallurgists, and Assayers, comprising the most recent improvements in the disintegration, amalgamation, smelting, and parting of the Precious Ores, with a Comprehensive Digest of the Mining Laws. Greatly augmented, revised, and corrected. By JULIUS SILVERSMITH. Fourth edition. Profusely illustrated. 1 vol. 12mo. Cloth. \$3.00.

One of the most important features of this work is that in which the metallurgy of the precious metals is treated of. In it the author has endeavored to embody all the processes for the reduction and manipulation of the precious ores heretofore successfully employed in Germany, England, Mexico, and the United States, together with such as have been more recently invented, and not yet fully tested—all of which are profusely illustrated and easy of comprehension.

## Simms' Levelling.

8vo. Cloth. \$2.50.

A TREATISE ON THE PRINCIPLES AND PRACTICE OF LEVELLING, showing its application to purposes of Railway Engineering and the Construction of Roads, &c. By FREDERICK W. SIMMS, C. E. From the fifth London edition, revised and corrected, with the addition of Mr. Law's Practical Examples for Setting Out Railway Curves. Illustrated with three lithographic plates and numerous wood-cuts.

"One of the most important text-books for the general surveyor, and there is scarcely a question connected with levelling for which a solution would be sought, but that would be satisfactorily answered by consulting this volume."  
—*Mining Journal*.

"The text-book on levelling in most of our engineering schools and colleges."—*Engineers*.

"The publishers have rendered a substantial service to the profession, especially to the younger members, by bringing out the present edition of Mr. Simms useful work."—*Engineering*.



## Stuart's Successful Engineer.

18mo. Boards. 50 cents.

HOW TO BECOME A SUCCESSFUL ENGINEER: Being Hints to Youths intending to adopt the Profession. By BERNARD STUART, Engineer. Sixth Edition.

"A valuable little book of sound, sensible advice to young men who wish to rise in the most important of the professions."—*Scientific American*.

## Stuart's Naval Dry Docks.

Twenty-four engravings on steel.

*Fourth Edition.*

4to. Cloth. \$6.00.

THE NAVAL DRY DOCKS OF THE UNITED STATES.

By CHARLES B. STUART. Engineer in Chief of the United States Navy.

### *List of Illustrations.*

Pumping Engine and Pumps—Plan of Dry Dock and Pump-Well—Sections of Dry Dock—Engine House—Iron Floating Gate—Details of Floating Gate—Iron Turning Gate—Plan of Turning Gate—Culvert Gate—Filling Culvert Gates—Engine Bed—Plate, Pumps, and Culvert—Engine House Roof—Floating Sectional Dock—Details of Section, and Plan of Turn-Tables—Plan of Basin and Marine Railways—Plan of Sliding Frame, and Elevation of Pumps—Hydraulic Cylinder—Plan of Gearing for Pumps and End Floats—Perspective View of Dock, Basin, and Railway—Plan of Basin of Portsmouth Dry Dock—Floating Balance Dock—Elevation of Trusses and the Machinery—Perspective View of Balance Dry Dock

## Free Hand Drawing.

Profusely Illustrated. 18mo. Boards. 50 cents.

A GUIDE TO ORNAMENTAL, Figure, and Landscape Drawing. By an Art Student.

CONTENTS.—Materials employed in Drawing, and how to use them—On Lines and how to Draw them—On Shading—Concerning lines and shading, with applications of them to simple elementary subjects—Sketches from Nature.

## Minifie's Mechanical Drawing.

*Eighth Edition.*


Royal 8vo. Cloth. \$4.00.

A TEXT-BOOK OF GEOMETRICAL DRAWING for the use of Mechanics and Schools, in which the Definitions and Rules of Geometry are familiarly explained; the Practical Problems are arranged, from the most simple to the more complex, and in their description technicalities are avoided as much as possible. With illustrations for Drawing Plans, Sections, and Elevations of Buildings and Machinery; an Introduction to Isometrical Drawing, and an Essay on Linear Perspective and Shadows. Illustrated with over 200 diagrams engraved on steel. By WM. MINIFIE, Architect. Eighth Edition. With an Appendix on the Theory and Application of Colors.

"It is the best work on Drawing that we have ever seen, and is especially a text-book of Geometrical Drawing for the use of Mechanics and Schools. No young Mechanic, such as a Machinist, Engineer, Cabinet-Maker, Millwright, or Carpenter, should be without it."—*Scientific American*.

"One of the most comprehensive works of the kind ever published, and cannot but possess great value to builders. The style is at once elegant and substantial."—*Pennsylvania Inquirer*.

"Whatever is said is rendered perfectly intelligible by remarkably well-executed diagrams on steel, leaving nothing for mere vague supposition; and the addition of an introduction to isometrical drawing, linear perspective, and the projection of shadows, winding up with a useful index to technical terms."—*Glasgow Mechanics' Journal*.

 The British Government has authorized the use of this book in their schools of art at Somerset House, London, and throughout the kingdom.

## Minifie's Geometrical Drawing.

*New Edition. Enlarged.*

12mo. Cloth. \$2.00.

GEOMETRICAL DRAWING. Abridged from the octavo edition, for the use of Schools. Illustrated with 48 steel plates. New edition, enlarged.

"It is well adapted as a text-book of drawing to be used in our High Schools and Academies where this useful branch of the fine arts has been hitherto too much neglected."—*Boston Journal*.

## Bell on Iron Smelting.

8vo. Cloth. \$6.00.

**CHEMICAL PHENOMENA OF IRON SMELTING.** An experimental and practical examination of the circumstances which determine the capacity of the Blast Furnace, the Temperature of the Air, and the Proper Condition of the Materials to be operated upon. By I. LOWTHIAN BELL.

"The reactions which take place in every foot of the blast-furnace have been investigated, and the nature of every step in the process, from the introduction of the raw material into the furnace to the production of the pig iron, has been carefully ascertained, and recorded so fully that any one in the trade can readily avail themselves of the knowledge acquired; and we have no hesitation in saying that the judicious application of such knowledge will do much to facilitate the introduction of arrangements which will still further economize fuel, and at the same time permit of the quality of the resulting metal being maintained, if not improved. The volume is one which no practical pig iron manufacturer can afford to be without if he be desirous of entering upon that competition which nowadays is essential to progress, and in issuing such a work Mr. Bell has entitled himself to the best thanks of every member of the trade."—*London Mining Journal*.

## King's Notes on Steam.

*Thirteenth Edition.*

8vo. Cloth. \$2.00.

**LESSONS AND PRACTICAL NOTES ON STEAM,** the Steam-Engine, Propellers, &c., &c., for Young Engineers, Students, and others. By the late W. R. KING, U. S. N. Revised by Chief-Engineer J. W. KING, U. S. Navy.

"This is one of the best, because eminently plain and practical treatises on the Steam Engine ever published."—*Philadelphia Press*.

This is the thirteenth edition of a valuable work of the late W. H. King, U. S. N. It contains lessons and practical notes on Steam and the Steam Engine, Propellers, etc. It is calculated to be of great use to young marine engineers, students, and others. The text is illustrated and explained by numerous diagrams and representations of machinery.—*Boston Daily Advertiser*.

Text-book at the U. S. Naval Academy, Annapolis.

## Burgh's Modern Marine Engineering.

One thick 4to vol. Cloth. \$25.00. Half morocco. \$30.00.

**MODERN MARINE ENGINEERING**, applied to Paddle and Screw Propulsion. Consisting of 36 Colored Plates, 259 Practical Wood-cut Illustrations, and 403 pages of Descriptive Matter, the whole being an exposition of the present practice of the following firms: Messrs. J. Penn & Sons; Messrs. Maudslay, Sons & Field; Messrs. James Watt & Co.; Messrs. J. & G. Rennie; Messrs. R. Napier & Sons; Messrs. J. & W. Dudgeon; Messrs. Ravenhill & Hodgson; Messrs. Humphreys & Tenant; Mr. J. T. Spencer, and Messrs. Forrester & Co. By N. P. BURGH, Engineer.

**PRINCIPAL CONTENTS.**—General Arrangements of Engines, 11 examples—General Arrangement of Boilers, 14 examples—General Arrangement of Superheaters, 11 examples—Details of Oscillating Paddle Engines, 34 examples—Condensers for Screw Engines, both Injection and Surface, 20 examples—Details of Screw Engines, 20 examples—Cylinders and Details of Screw Engines, 21 examples—Slide Valves and Details, 7 examples—Slide Valve, Link Motion, 7 examples—Expansion Valves and Gear, 10 examples—Details in General, 30 examples—Screw Propeller and Fittings, 13 examples—Engine and Boiler Fittings, 28 examples—In relation to the Principles of the Marine Engine and Boiler, 33 examples.

### *Notices of the Press.*

"Every conceivable detail of the Marine Engine, under all its various forms, is profusely, and we must add, admirably illustrated by a multitude of engravings, selected from the best and most modern practice of the first Marine Engineers of the day. The chapter on Condensers is peculiarly valuable. In one word, there is no other work in existence which will bear a moment's comparison with it as an exponent of the skill, talent and practical experience to which is due the splendid reputation enjoyed by many British Marine Engineers."—*Engineer*.

"This very comprehensive work, which was issued in Monthly parts, has just been completed. It contains large and full drawings and copious descriptions of most of the best examples of Modern Marine Engines, and it is a complete theoretical and practical treatise on the subject of Marine Engineering."—*American Artisan*.

This is the only edition of the above work with the beautifully colored plates, and it is out of print in England.

## Bourne's Treatise on the Steam Engine.

*Ninth Edition.*

Illustrated. 4to. Cloth. \$15.00.

TREATISE ON THE STEAM ENGINE in its various applications to Mines, Mills, Steam Navigation, Railways, and Agriculture, with the theoretical investigations respecting the Motive Power of Heat and the proper Proportions of Steam Engines. Elaborate Tables of the right dimensions of every part, and Practical Instructions for the Manufacture and Management of every species of Engine in actual use. By JOHN BOURNE, being the ninth edition of "A Treatise on the Steam Engine," by the "Artisan Club." Illustrated by thirty-eight plates and five hundred and forty-six wood-cuts.

As Mr. Bourne's work has the great merit of avoiding unsound and immature views, it may safely be consulted by all who are really desirous of acquiring trustworthy information on the subject of which it treats. During the twenty-two years which have elapsed from the issue of the first edition, the improvements introduced in the construction of the steam engine have been both numerous and important, and of these Mr. Bourne has taken care to point out the more prominent, and to furnish the reader with such information as shall enable him readily to judge of their relative value. This edition has been thoroughly modernized, and made to accord with the opinions and practice of the more successful engineers of the present day. All that the book professes to give is given with ability and evident care. The scientific principles which are permanent are admirably explained, and reference is made to many of the more valuable of the recently introduced engines. To express an opinion of the value and utility of such a work as *The Artisan Club's Treatise on the Steam Engine*, which has passed through eight editions already, would be superfluous; but it may be safely stated that the work is worthy the attentive study of all either engaged in the manufacture of steam engines or interested in economizing the use of steam.—*Mining Journal*.

## Isherwood's Engineering Precedents.

Two Vols. in One. 8vo. Cloth. \$2.50.

ENGINEERING PRECEDENTS FOR STEAM MACHINERY.

Arranged in the most practical and useful manner for Engineers.

By B. F. ISHERWOOD, Civil Engineer, U. S. Navy. With illustrations.

## Ward's Steam for the Million.

*New and Revised Edition.*

8vo. Cloth. \$1.00.

STEAM FOR THE MILLION. A Popular Treatise on Steam and its Application to the Useful Arts, especially to Navigation. By J. H. WARD, Commander U. S. Navy. New and revised edition.

A most excellent work for the young engineer and general reader. Many facts relating to the management of the boiler and engine are set forth with a simplicity of language and perfection of detail that bring the subject home to the reader.—*American Engineer*.

---

## Walker's Screw Propulsion.

8vo. Cloth. 75 cents.

NOTES ON SCREW PROPULSION, its Rise and History. By Capt. W. H. WALKER, U. S. Navy.

Commander Walker's book contains an immense amount of concise practical data, and every item of information recorded fully proves that the various points bearing upon it have been well considered previously to expressing an opinion.—*London Mining Journal*.

---

## Page's Earth's Crust.

18mo. Cloth. 75 cents.

THE EARTH'S CRUST: a Handy Outline of Geology. By DAVID PAGE.

"Such a work as this was much wanted—a work giving in clear and intelligible outline the leading facts of the science, without amplification or irksome details. It is admirable in arrangement, and clear and easy, and, at the same time, forcible in style. It will lead, we hope, to the introduction of Geology into many schools that have neither time nor room for the study of large treatises."—*The Museum*.

## **Rogers' Geology of Pennsylvania.**

3 Vols. 4to, with Portfolio of Maps. Cloth. \$30.00.

**THE GEOLOGY OF PENNSYLVANIA.** A Government Survey. With a general view of the Geology of the United States, Essays on the Coal Formation and its Fossils, and a description of the Coal Fields of North America and Great Britain. By **HENRY DARWIN ROGERS**, Late State Geologist of Pennsylvania. Splendidly illustrated with Plates and Engravings in the Text.

It certainly should be in every public library throughout the country, and likewise in the possession of all students of Geology. After the final sale of these copies, the work will, of course, become more valuable.

The work for the last five years has been entirely out of the market, but a few copies that remained in the hands of Prof. Rogers, in Scotland, at the time of his death, are now offered to the public, at a price which is even below what it was originally sold for when first published.

---

## **Morfit on Pure Fertilizers.**

With 28 Illustrative Plates. 8vo. Cloth. \$20.00.

**A PRACTICAL TREATISE ON PURE FERTILIZERS**, and the Chemical Conversion of Rock Guanos, Marlstones, Coprolites, and the Crude Phosphates of Lime and Alumina Generally, into various Valuable Products. By **CAMPBELL MORFIT**, M.D., F.C.S.

---

## **Sweet's Report on Coal.**

8vo. Cloth. \$3.00.

**SPECIAL REPORT ON COAL**; showing its Distribution, Classification, and Cost delivered over different routes to various points in the State of New York, and the principal cities on the Atlantic Coast. By **S. H. SWEET**. With maps.

---

## **Colburn's Gas Works of London.**

12mo. Boards. 60 cents.

**GAS WORKS OF LONDON.** By **ZERAH COLBURN**.

## The Useful Metals and their Alloys; Scoffren, Truran, and others.

*Fifth Edition.*

8vo. Half calf. \$3.75.

THE USEFUL METALS AND THEIR ALLOYS, including MINING VENTILATION, MINING JURISPRUDENCE AND METALLURGIC CHEMISTRY employed in the conversion of IRON, COPPER, TIN, ZINC, ANTIMONY, AND LEAD ORES, with their applications to THE INDUSTRIAL ARTS. By JOHN SCOFFREN, WILLIAM TRURAN, WILLIAM CLAY, ROBERT OXLAND, WILLIAM FAIRBAIRN, W. C. AITKIN, and WILLIAM VOSE PICKETT.

## Collins' Useful Alloys.

18mo. Flexible. 75 cents.

THE PRIVATE BOOK OF USEFUL ALLOYS and Memoranda for Goldsmiths, Jewellers, etc. By JAMES E. COLLINS

This little book is compiled from notes made by the Author from the papers of one of the largest and most eminent Manufacturing Goldsmiths and Jewellers in this country, and as the firm is now no longer in existence, and the Author is at present engaged in some other undertaking, he now offers to the public the benefit of his experience, and in so doing he begs to state that all the alloys, etc., given in these pages may be confidently relied on as being thoroughly practicable.

The Memoranda and Receipts throughout this book are also compiled from practice, and will no doubt be found useful to the practical jeweller. —*Shirley, July, 1871.*

## Joynson's Metals Used in Construction.

12mo. Cloth. 75 cents.

THE METALS USED IN CONSTRUCTION: Iron, Steel, Bessemer Metal, etc., etc. By FRANCIS HERBERT JOYNSON. Illustrated.

"In the interests of practical science, we are bound to notice this work; and to those who wish further information, we should say, buy it; and the outlay, we honestly believe, will be considered well spent." —*Scientific Review.*



## Holley's Ordnance and Armor.

493 Engravings. Half Roan, \$10.00. Half Russia, \$12.00.

**A TREATISE ON ORDNANCE AND ARMOR**—Embracing Descriptions, Discussions, and Professional Opinions concerning the MATERIAL, FABRICATION, Requirements, Capabilities, and Endurance of European and American Guns, for Naval, Sea Coast, and Iron-clad Warfare, and their RIFLING, PROJECTILES, and BREECH-LOADING; also, Results of Experiments against Armor, from Official Records, with an Appendix referring to Gun-Cotton, Hooped Guns, etc., etc. By ALEXANDER L. HOLLEY, B. P. 948 pages, 493 Engravings, and 147 Tables of Results, etc.

### CONTENTS.

CHAPTER I.—Standard Guns and their Fabrication Described: Section 1. Hooped Guns; Section 2. Solid Wrought Iron Guns; Section 3. Solid Steel Guns; Section 4. Cast-Iron Guns. CHAPTER II.—The Requirements of Guns, Armor: Section 1. The Work to be done; Section 2. Heavy Shot at Low Velocities; Section 3. Small Shot at High Velocities; Section 4. The two Systems Combined; Section 5. Breaching Masonry. CHAPTER III.—The Strains and Structure of Guns: Section 1. Resistance to Elastic Pressure; Section 2. The Effects of Vibration; Section 3. The Effects of Heat. CHAPTER IV.—Cannon Metals and Processes of Fabrication: Section 1. Elasticity and Ductility; Section 2. Cast-Iron; Section 3. Wrought Iron; Section 4. Steel; Section 5. Bronze; Section 6. Other Alloys. CHAPTER V.—Rifling and Projectiles; Standard Forms and Practice Described; Early Experiments; The Centring System; The Compressing System; The Expansion System; Armor Punching Projectiles; Shells for Molten Metal; Competitive Trial of Rifled Guns, 1862; Duty of Rifled Guns: General Uses, Accuracy, Range, Velocity, Strain, Liability of Projectile to Injury; Firing Spherical Shot from Rifled Guns; Material for Armor-Punching Projectiles; Shape of Armor-Punching Projectiles; Capacity and Destructiveness of Shells; Elongated Shot from Smooth Bores; Conclusions; Velocity of Projectiles (Table). CHAPTER VI.—Breech-Loading Advantages and Defects of the System; Rapid Firing and Cooling Guns by Machinery; Standard Breech-Loaders Described. Part Second: Experiments against Armor; Account of Experiments from Official Records in Chronological Order. APPENDIX.—Report on the Application of Gun-Cotton to Warlike Purposes—British Association, 1863; Manufacture and Experiments in England; Guns Hooped with Initial Tension—History; How Guns Burst, by Wiard, Lyman's Accelerating Gun; Endurance of Parrott and Whitworth Guns at Charleston; Hooping old United States Cast-Iron Guns; Endurance and Accuracy of the Armstrong 600-pounder; Competitive Trials with 7-inch Guns.

## Peirce's Analytic Mechanics.

4to. Cloth. \$10.00.

**SYSTEM OF ANALYTIC MECHANICS.** Physical and Celestial Mechanics. By BENJAMIN PEIRCE, Perkins Professor of Astronomy and Mathematics in Harvard University, and Consulting Astronomer of the American Ephemeris and Nautical Almanac. Developed in four systems of Analytic Mechanics, Celestial Mechanics, Potential Physics, and Analytic Morphology.

"I have re-examined the memoirs of the great geometers, and have striven to consolidate their latest researches and their most exalted forms of thought into a consistent and uniform treatise. If I have hereby succeeded in opening to the students of my country a readier access to these choice jewels of intellect; if their brilliancy is not impaired in this attempt to reset them; if, in their own constellation, they illustrate each other, and concentrate a stronger light upon the names of their discoverers, and, still more, if any gem which I may have presumed to add is not wholly lustreless in the collection, I shall feel that my work has not been in vain."—*Extract from the Preface.*

## Burt's Key to Solar Compass.

*Second Edition.*

Pocket Book Form. Tuck. \$2.50.

**KEY TO THE SOLAR COMPASS, and Surveyor's Companion;** comprising all the Rules necessary for use in the field; also, Description of the Linear Surveys and Public Land System of the United States, Notes on the Barometer, Suggestions for an outfit for a Survey of four months, etc., etc., etc. By W. A. BURT, U. S. Deputy Surveyor. Second edition.

## Chauvenet's Lunar Distances.

8vo. Cloth. \$2.00.

**NEW METHOD OF CORRECTING LUNAR DISTANCES,** and Improved Method of Finding the Error and Rate of a Chronometer, by equal altitudes. By WM. CHAUVENET, LL.D., Chancellor of Washington University of St. Louis.

## Jeffers' Nautical Surveying.

Illustrated with 9 Copperplates and 31 Wood-cut Illustrations. 8vo.

Cloth. \$5.00.

**NAUTICAL SURVEYING.** By **WILLIAM N. JEFFERS**, Captain  
U. S. Navy.

Many books have been written on each of the subjects treated of in the sixteen chapters of this work; and, to obtain a complete knowledge of geodetic surveying requires a profound study of the whole range of mathematical and physical sciences; but a year of preparation should render any intelligent officer competent to conduct a nautical survey.

**CONTENTS.**—Chapter I. Formulæ and Constants Useful in Surveying II. Distinctive Character of Surveys. III. Hydrographic Surveying under Sail; or, Running Survey. IV. Hydrographic Surveying of Boats; or, Harbor Survey. V. Tides—Definition of Tidal Phenomena—Tidal Observations. VI. Measurement of Bases—Appropriate and Direct. VII. Measurement of the Angles of Triangles—Azimuths—Astronomical Bearings. VIII. Corrections to be Applied to the Observed Angles. IX. Levelling—Difference of Level. X. Computation of the Sides of the Triangulation—The Three-point Problem. XI. Determination of the Geodetic Latitudes, Longitudes, and Azimuths, of Points of a Triangulation. XII. Summary of Subjects treated of in preceding Chapters—Examples of Computation by various Formulæ. XIII. Projection of Charts and Plans. XIV. Astronomical Determination of Latitude and Longitude. XV. Magnetic Observations. XVI. Deep Sea Soundings. XVII. Tables for Ascertaining Distances at Sea, and a full Index.

### *List of Plates.*

Plate I. Diagram Illustrative of the Triangulation. II. Specimen Page of Field Book. III. Running Survey of Coast. IV. Example of a Running Survey from Belcher. V. Flying Survey of an Island. VI. Survey of a Shoal. VII. Boat Survey of a River. VIII. Three-Point Problem. IX. Triangulation.

## Coffin's Navigation.

*Fifth Edition.*

12mo. Cloth. \$3.50.

**NAVIGATION AND NAUTICAL ASTRONOMY.** Prepared for the use of the U. S. Naval Academy. By **J. H. C. COFFIN**, Prof. of Astronomy, Navigation and Surveying; with 52 wood-cut illustrations.

## Clark's Theoretical Navigation.

8vo. Cloth. \$3.00.

**THEORETICAL NAVIGATION AND NAUTICAL ASTRONOMY.** By LEWIS CLARK, Lieut.-Commander, U. S. Navy. Illustrated with 41 Woodcuts, including the Vernier.

Prepared for Use at the U. S. Naval Academy.

## The Plane Table.

Illustrated. 8vo. Cloth. \$3.00.

**ITS USES IN TOPOGRAPHICAL SURVEYING.** From the Papers of the U. S. Coast Survey.

This work gives a description of the Plane Table employed at the U. S. Coast Survey Office, and the manner of using it.

## Pook on Shipbuilding.

8vo. Cloth. \$5.00.

**METHOD OF COMPARING THE LINES AND DRAUGHTING VESSELS PROPELLED BY SAIL OR STEAM,** including a Chapter on Laying off on the Mould-Loft Floor. By SAMUEL M. POOK, Naval Constructor. 1 vol., 8vo. With illustrations. Cloth. \$5.00.

## Brunnow's Spherical Astronomy.

8vo. Cloth. \$6.50.

**SPHERICAL ASTRONOMY.** By F. BRUNNOW, Ph. Dr. Translated by the Author from the Second German edition. 10 1/2

## Van Buren's Formulas.

8vo. Cloth. \$2.00.

**INVESTIGATIONS OF FORMULAS**, for the Strength of the Iron Parts of Steam Machinery. By J. D. VAN BUREN, Jr., C. E. Illustrated.

This is an analytical discussion of the formulæ employed by mechanical engineers in determining the rupturing or crippling pressure in the different parts of a machine. The formulæ are founded upon the principle, that the different parts of a machine should be equally strong, and are developed in reference to the ultimate strength of the material in order to leave the choice of a factor of safety to the judgment of the designer. — *Silliman's Journal*.

## Joynson on Machine Gearing.

8vo. Cloth. \$2.00.

**THE MECHANIC'S AND STUDENT'S GUIDE** in the Designing and Construction of General Machine Gearing, as Eccentrics, Screws, Toothed Wheels, etc., and the Drawing of Rectilineal and Curved Surfaces; with Practical Rules and Details. Edited by FRANCIS HERBERT JOYNSON. Illustrated with 18 folded plates.

"The aim of this work is to be a guide to mechanics in the designing and construction of general machine-gearing. This design it well fulfils, being plainly and sensibly written, and profusely illustrated." — *Sunday Times*.

## Barnard's Report, Paris Exposition, 1867.

Illustrated. 8vo. Cloth. \$5.00.

**REPORT ON MACHINERY AND PROCESSES ON THE INDUSTRIAL ARTS AND APPARATUS OF THE EXACT SCIENCES.** By F. A. P. BARNARD, LL.D.—Paris Universal Exposition, 1867.

"We have in this volume the results of Dr. Barnard's study of the Paris Exposition of 1867, in the form of an official Report of the Government. It is the most exhaustive treatise upon modern inventions that has appeared since the Universal Exhibition of 1851, and we doubt if anything equal to it has appeared this century." — *Journal Applied Chemistry*.

## Engineering Facts and Figures.

18mo. Cloth. \$2.50 per Volume.

AN ANNUAL REGISTER OF PROGRESS IN MECHANICAL ENGINEERING AND CONSTRUCTION, for the Years 1863-64-65-66-67-68. Fully illustrated. 6 volumes.

Each volume sold separately.

## Beckwith's Pottery.

8vo. Paper. 60 cents.

OBSERVATIONS ON THE MATERIALS and Manufacture of Terra-Cotta, Stone-Ware, Fire-Brick, Porcelain and Encaustic Tiles, with Remarks on the Products exhibited at the London International Exhibition, 1871. By ARTHUR BECKWITH, Civil Engineer.

"Everything is noticed in this book which comes under the head of Pottery, from fine porcelain to ordinary brick, and aside from the interest which all take in such manufactures, the work will be of considerable value to followers of the ceramic-art."—*Evening Mail*.

## Dodd's Dictionary of Manufactures, etc.

12mo. Cloth. \$2.00.

DICTIONARY OF MANUFACTURES, MINING, MACHINERY, AND THE INDUSTRIAL ARTS. By GEORGE DODD.

This work, a small book on a great subject, treats, in alphabetical arrangement, of those numerous matters which come generally within the range of manufactures and the productive arts. The raw materials—animal, vegetable, and mineral—whence the manufactured products are derived, are succinctly noticed in connection with the processes which they undergo, but not as subjects of natural history. The operations of the Mine and the Mill, the Foundry and the Forge, the Factory and the Workshop, are passed under review. The principal machines and engines, tools and apparatus, concerned in manufacturing processes, are briefly described. The scale on which our chief branches of national industry are conducted, in regard to values and quantities, is indicated in various ways.

## Stuart's Civil and Military Engineering of America.

8vo. Illustrated. Cloth. \$5.00.

### THE CIVIL AND MILITARY ENGINEERS OF AMERICA.

By General CHARLES B. STUART, Author of "Naval Dry Docks of the United States," etc., etc. Embellished with nine finely executed portraits on steel of eminent engineers, and illustrated by engravings of some of the most important and original works constructed in America.

Containing sketches of the Life and Works of Major Andrew Ellicott, James Geddes (with Portrait), Benjamin Wright (with Portrait), Canvass White (with Portrait), David Stanhope Bates, Nathan S. Roberts, Gridley Bryant (with Portrait), General Joseph G. Swift, Jesse L. Williams (with Portrait), Colonel William McRee, Samuel H. Kneass, Captain John Childre with Portrait, Frederick Harbach, Major David Bates Douglas with Portrait, Jonathan Knight, Benjamin H. Latrobe (with Portrait), Colonel Charles Ellet, Jr. (with Portrait), Samuel Forrer, William Stuart Watson, John A. Roebling.

## Alexander's Dictionary of Weights and Measures.

8vo. Cloth. \$3.50.

UNIVERSAL DICTIONARY OF WEIGHTS AND MEASURES, Ancient and Modern, reduced to the standards of the United States of America. By J. H. ALEXANDER. New edition. 1 vol.

"As a standard work of reference, this book should be in every library; it is one which we have long wanted, and it will save much trouble and research."—*Scientific American*.

## Gouge on Ventilation.

*Third Edition Enlarged.*

8vo. Cloth. \$2.00.

NEW SYSTEM OF VENTILATION, which has been thoroughly tested under the patronage of many distinguished persons. By HENRY A. GOUGE, with many illustrations.

## Saeltzer's Acoustics.

12mo. Cloth. \$2.00.

TREATISE ON ACOUSTICS in Connection with Ventilation.

With a new theory based on an important discovery, of facilitating clear and intelligible sound in any building. By ALEXANDER SAELTZER.

"A practical and very sound treatise on a subject of great importance to architects, and one to which there has hitherto been entirely too little attention paid. The author's theory is, that, by bestowing proper care upon the point of Acoustics, the requisite ventilation will be obtained, and *vice versa*.—*Brooklyn Union*.

## Myer's Manual of Signals.

*New Edition. Enlarged.*

12mo. 48 Plates full Roan. \$5.00.

MANUAL OF SIGNALS, for the Use of Signal Officers in the Field, and for Military and Naval Students, Military Schools, etc. A new edition, enlarged and illustrated. By Brig.-Gen. ALBERT J. MYER, Chief Signal Officer of the Army, Colonel of the Signal Corps during the War of the Rebellion.

## Larrabee's Secret Letter and Telegraph Code.

18mo. Cloth. \$1.00.

CIPHER AND SECRET LETTER AND TELEGRAPHIC CODE, with Hogg's Improvements. The most perfect secret Code ever invented or discovered. Impossible to read without the Key. Invaluable for Secret, Military, Naval, and Diplomatic Service, as well as for Brokers, Bankers, and Merchants. By C. S. LARRABEE, the original inventor of the scheme.



## Hunt's Designs for Central Park Gateways.

4to. Cloth. \$5.00.

DESIGNS FOR THE GATEWAYS OF THE SOUTHERN ENTRANCES TO THE CENTRAL PARK. By RICHARD M. HUNT. With a description of the designs.

## Pickert and Metcalf's Art of Graining.

1 vol. 4to. Cloth. \$10.00.

THE ART OF GRAINING. How Acquired and How Produced, with description of colors and their application. By CHARLES PICKERT and ABRAHAM METCALF. Beautifully illustrated with 42 tinted plates of the various woods used in interior finishing. Tinted paper.

The authors present here the result of long experience in the practice of this decorative art, and feel confident that they hereby offer to their brother artisans a reliable guide to improvement in the practice of graining.

## Portrait Gallery of the War.

60 fine Portraits on Steel. Royal 8vo. Cloth. \$6.00.

PORTRAIT GALLERY OF THE WAR, CIVIL, MILITARY AND NAVAL. A Biographical Record. Edited by FRANK MOORE.

## One Law in Nature.

12mo. Cloth. \$1.50.

ONE LAW IN NATURE. By Capt. H. M. LAZELLE, U. S. A. A New Corpuscular Theory, comprehending Unity of Force, Identity of Matter, and its Multiple Atom Constitution, applied to the Physical Affections or Modes of Energy.

## Ernst's Manual of Military Engineering.

193 Wood Cuts and 3 Lithographed Plates. 12mo. Cloth. \$5.00.

A MANUAL OF PRACTICAL MILITARY ENGINEERING. Prepared for the use of the Cadets of the U. S. Military Academy, and for Engineer Troops. By Capt. O. H. ERNST, Corps of Engineers, Instructor in Practical Military Engineering, U. S. Military Academy.

## Church's Metallurgical Journey.

24 Illustrations. 8vo. Cloth. \$2.00.

NOTES OF A METALLURGICAL JOURNEY IN EUROPE. By JOHN A. CHURCH, Engineer of Mines.

## Blake's Precious Metals.

8vo. Cloth. \$2.00.

REPORT UPON THE PRECIOUS METALS: Being Statistical Notices of the principal Gold and Silver producing regions of the World. Represented at the Paris Universal Exposition. By WILLIAM P. BLAKE, Commissioner from the State of California.

## Clevenger's Surveying.

Illustrated Pocket Form. Morocco Gilt. \$2.50.

A TREATISE ON THE METHOD OF GOVERNMENT SURVEYING, as prescribed by the United States Congress, and Commissioner of the General Land Office. With complete Mathematical, Astronomical and Practical Instructions, for the use of the United States Surveyors in the Field, and Students who contemplate engaging in the business of Public Land Surveying. By S. R. CLEVENGER, U. S. Deputy Surveyor.

"The reputation of the author as a surveyor guarantees an exhaustive treatise on this subject."—*Dakota Register*.

"Surveyors have long needed a text-book of this description."—*The Press*.

## **Bow on Bracing.**

156 Illustrations on Stone. 8vo. Cloth. \$1.50.

A TREATISE ON BRACING, with its application to Bridges and other Structures of Wood or Iron. By ROBERT HENRY BOW, C. E.

## **Howard's Earthwork Mensuration.**

8vo. Illustrated. Cloth. \$1.50.

EARTHWORK MENSURATION ON THE BASIS OF THE PRISMOIDAL FORMULÆ. Containing simple and labor-saving method of obtaining Prismoidal Contents directly from End Areas. Illustrated by Examples, and accompanied by Plain Rules for practical uses. By CONWAY R. HOWARD, Civil Engineer, Richmond, Va.

## **McAlpine's Modern Engineering.**

Second Edition. 8vo. Cloth. \$1.50.

MODERN ENGINEERING. A Lecture delivered at the American Institute in New York. By WILLIAM J. MCALPINE.

## **Mowbray's Tri-Nitro-Glycerine.**

8vo. Cloth. Illustrated. \$3.00.

TRI-NITRO-GLYCERINE, as applied in the Hoosac Tunnel, and to Submarine Blasting, Torpedoes, Quarrying, etc. Being the result of six years' observation and practice during the manufacture of five hundred thousand pounds of this explosive, Mica Blasting Powder, Dynamites; with an account of

the various Systems of Blasting by Electricity, Priming Compounds, Explosives, etc., etc. By GEORGE M. MOWBRAY, Operative Chemist, with thirteen illustrations, tables, and appendix. Third Edition. Re-written.

---

### Wanklyn's Milk Analysis.

12mo. Cloth. \$1.00.

MILK ANALYSIS. A Practical Treatise on the Examination of Milk, and its Derivatives, Cream, Butter and Cheese. By J. ALFRED WANKLYN, M. R. C. S.

---

### Toner's Dictionary of Elevations.

8vo. Paper, \$3.00. Cloth, \$3.75.

DICTIONARY OF ELEVATIONS AND CLIMATIC REGISTER OF THE UNITED STATES. Containing, in addition to Elevations, the Latitude, Mean Annual Temperature, and the total Annual Rain Fall of many localities; with a brief Introduction on the Orographic and Physical Peculiarities of North America. By J. M. TONER, M. D.

---

### Adams. Sewers and Drains.

(In Press.)

SEWERS AND DRAINS FOR POPULOUS DISTRICTS. Embracing Rules and Formulas for the dimensions of Sanitary Engineers. By JULIUS W. ADAMS, Chief Engineer of the Board of City Works, Brooklyn.

SILVER MINING REGIONS OF COLORADO, with some account of the different Processes now being introduced for working the Gold Ores of that Territory. By J. P. WHITNEY. 12mo. Paper. 25 cents.

---

COLORADO: SCHEDULE OF ORES contributed by sundry persons to the Paris Universal Exposition of 1867, with some information about the Region and its Resources. By J. P. WHITNEY, Commissioner from the Territory. 8vo. Paper, with Maps. 25 cents.

---

THE SILVER DISTRICTS OF NEVADA. With Map. 8vo. Paper. 35 cents.

---

ARIZONA: ITS RESOURCES AND PROSPECTS. By Hon. R. C. McCORMICK, Secretary of the Territory. With Map. 8vo. Paper. 25 cents.

---

MONTANA AS IT IS: Being a general description of its Resources, both Mineral and Agricultural; including a complete description of the face of the country, its climate, etc. Illustrated with a Map of the Territory, showing the different Roads and the location of the different Mining Districts. To which is appended a complete Dictionary of THE SNAKE LANGUAGE, and also of the famous Chinook Jargon, with numerous critical and explanatory Notes. By GRANVILLE STUART. 8vo. Paper. \$2.00.

---

RAILWAY GAUGES. A Review of the Theory of Narrow Gauges as applied to Main Trunk Lines of Railway. By SILAS SEYMOUR, Genl. Consulting Engineer. 8vo. Paper. 50 cents.

---

REPORT made to the President and Executive Board of the Texas Pacific Railroad. By Gen. G. P. BUELL, Chief Engineer. 8vo. Paper. 75 cents.

## Van Nostrand's Science Series.

It is the intention of the Publisher of this Series to issue them at intervals of about a month. They will be put up in a uniform, neat and attractive form, 18mo, fancy boards. The subjects will be of an eminently scientific character, and embrace as wide a range of topics as possible, all of the highest character.

Price, 50 Cents Each.

1.

CHIMNEYS FOR FURNACES, FIRE-PLACES, AND STEAM BOILERS. By R. ARMSTRONG, C. E.

2.

STEAM BOILER EXPLOSIONS. By ZERAH COLBURN.

3.

PRACTICAL DESIGNING OF RETAINING WALLS  
By ARTHUR JACOB, A. B. With Illustrations.

4.

PROPORTIONS OF PINS USED IN BRIDGES. By  
CHARLES E. BENDER, C. E. With Illustrations.

5.

VENTILATION OF BUILDINGS. By W. F. BUTLER. With  
Illustrations.

6.

ON THE DESIGNING AND CONSTRUCTION OF STORAGE RESERVOIRS. By ARTHUR JACOB. With Illustrations.

7.

SURCHARGED AND DIFFERENT FORMS OF RETAINING WALLS. By JAMES S. TATE, C. E.

8.

A TREATISE ON THE COMPOUND ENGINE. By JOHN TURNBULL. With Illustrations.

9.

FUEL. By C. WILLIAM SIEMENS, to which is appended the value of ARTIFICIAL FUELS AS COMPARED WITH COAL.  
By JOHN WORMALD, C. E.

10.—COMPOUND ENGINES. Translated from the French of  
A. MALLET. With Illustrations.

11.—THEORY OF ARCHES. By Prof. W. ALLAN. With Illustrations.

\* \* Other Works in preparation.









